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EDITORIAL

MAIZE BREEDING

IN many Colonial territories work is being directed towards the improvement of the maize crop and both Plant Breeders and Agricultural Officers are frequently confronted with the problem of the most suitable technique to adopt in relation to local circumstances. Moreover the production of hybrid maize is often advocated with little realization of the implications and of the scope of the work necessary for its production. Departmental officers have difficulty in obtaining in concise form up-to-date information on the problems associated with maize breeding and for this reason the article by Dr. William L. Brown on pages 86–96 will, it is felt, be welcomed by those whose work brings them into contact with this important crop.

Dr. Brown, who is a Fulbright Research Scholar, has been working during the past year at the Imperial College of Tropical Agriculture and the College has been fortunate in having as a colleague one who is an acknowledged authority on this particular subject.—A.B.K.

REVIEW ARTICLES, BOOK REVIEWS AND ABSTRACTS

TROPICAL CROPS, GENERAL AGRICULTURE

THE CACAO INDUSTRY OF WESTERN SAMOA

Summary of a Report compiled by D. A. Donald, Senior Agricultural Officer, British Solomon Islands Protectorate, between November, 1951 *and February,* 1952

WESTERN SAMOA comprises two large and several smaller islands with a total area of about 1,130 square miles. They are mainly volcanic, with steep mountain ranges rising to 6,000 feet and are surrounded by coral reefs. The cacao plantations occupy the easy slopes from sea level up to 700 feet.

The climate is equable and humid, with an average rainfall of 127 inches at Apia. The wet season lasts from November to April and the dry season from May to October.

The main crop season is from September to December and there is a secondary crop from April to June.

Soils are in general shallow, volcanic and rocky, but fertile. All except those in the very high rainfall area have a good crumb structure and a loose subsoil which ensures free root development, ample aeration and good drainage.

Cacao was first planted on a commercial scale by the Germans in 1884, apparently with Venezuelan Criollo. Although this variety showed great promise and yielded well, it proved highly susceptible to canker (*Phytophthora palmivora*) and the young industry was almost abandoned. Forastero varieties were then introduced from Ceylon and interplanted with the Criollo, thereby producing the present hybrid population. Production has risen fairly steadily since 1900, and in 1951 3,212 tons of dry cacao, valued at some £800,000 were exported.

Recently, selection has disclosed an outstanding tree (Lafi No. 7) which in 1950 produced 288 pods averaging 6 ozs. wet beans per pod. Of more interest still is the fact that, during the four years it has been under observation, this tree has not produced a single black pod.

Plantations are usually established by planting seed at stake and the dense growth of pawpaw (*Carica papaya*) which generally springs up when land is cleared, is used as the primary shade. Secondary shade, usually Dadap (*Erythrina spp.*) with or without bananas in association, follows later. The standard planting interval is 16 x 16 ft., giving 170 trees per acre. It is generally considered that windbreaks are unnecessary as cacao is only planted

in sheltered localities. In Samoa the shade trees are never allowed to grow taller than the cacao trees ; the object is a closed canopy and it is the *soil* which is shaded, not the cacao trees themselves.

The plantation industry is highly efficient and produces a well-dried, cleaned and graded product of high quality. The beans are fermented for 5 to 6 days and usually dried by artificial heat. The beans are washed after fermentation and before drying. Peasant grown cacao, however, still produces approximately half of the total crop and here again the quality of the product is usually high. Fermentation and washing are almost routine practices and most of the cacao is thoroughly sun-dried.

Pink Disease (*Corticium salmonicolor*) and Canker (*Phytophthora palmivora*) are of some importance and are treated regularly on the estates, and on the whole the incidence of diseases and pests is kept at a very low level. Rats, which damage ripening pods, are destroyed by poison baits.

The overall picture is one of a flourishing small industry, no more than one-third the size of the Trinidad cacao industry, which is in itself insignificant when compared with West Africa. Standards of cultivation by both estates and peasants alike are high, resulting in a uniformly excellent product which commands a high price.—R.E.D.B.

FARMER AND STOCK-BREEDER YEAR BOOK 1953

"Farmer and Stock-Breeder Year Book 1953". *The 77th edition, published on December 8th,* 1952 *by Farmer and Stock-Breeder Publications Limited, Dorset House, Stamford Street, London, S.E.*1. *Size D8vo.* $8\frac{3}{4}''$ x $5\frac{1}{2}''$. *Over* 390 *pages. Price* 10*s.* 6*d.* (*Postage* 6*d.*)

This annual is termed by the Publishers "A book of reference for farmers and all connected with agriculture". For such persons in the British Isles it amply fulfils this statement, but it is doubtful whether it would be of much value to agricultural workers in the Tropics. There are, however, two articles of international interest, namely, one on Food Production by Morris E. Dodd, pp. 68–71, and the International aspect of Foot and Mouth Disease, pp. 72–75.

There is an excellent illustrated section on new Agricultural Machinery and the series of photographs depicting the breed-champions of the year of all classes of livestock is well produced. There is also a wealth of information regarding livestock societies and sales, livestock feeding and on many other facets of agriculture.

It is perhaps a sign of the times that it is thought necessary to include an article on the formal legal notices which unfortunately have to be dealt with by the modern farmer.—G.W.H.W.

A SURVEY OF THE TRADE IN AGRICULTURAL MACHINERY

Thirty-sixth Report of the Commonwealth Economic Committee. 1952. *H.M.S.O., London. Pp.* vi+174. *Price* 7*s.* 6*d.*

ALTHOUGH primarily of interest to the economist or the agricultural machinery manufacturer concerned in assessing and exploiting possible world markets, this factual report of the *Commonwealth Economic Committee* is of value to the agriculturist interested in the development of mechanised agriculture.

The report is largely concerned with statistics relating to the import and export of tractors and agricultural implements in various countries of the world and only brief comments are made concerning these statistics. Certainly no opinions are expressed regarding suitability, or otherwise, of the machinery mentioned and it is obviously not the object of the work to arrive at such conclusions. However the critical observer can use the figures to establish for himself a picture of the pattern and extent of mechanised agricultural development in any locality while the relative numbers of the various types of implements in use provide a pointer towards the type of equipment likely to be most satisfactory in any given area.

Some opinions are expressed, however, regarding the difficulties to be overcome in introducing mechanised agricultural practices in each area and the authors mention the types of equipment which they consider are most likely to be first in demand.

This report gives a general image of the state of world agricultural mechanisation reflected, as it were, in the mirror of the volume of trade, and it is this that the agriculturists will find of the greatest value.—P.H.R.

PLANT AND ANIMAL NUTRITION

ROLE OF COPPER IN CROP PRODUCTION

BY

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INTRODUCTION

COPPER salts were known for a long time to control certain plant diseases when applied as sprays but the essentiality of copper as an element in plant nutrition was only lately recognised (56). Copper belongs to group IV of Thatcher's classification of elements of plant nutrition, playing an important part in oxidation-reduction reactions in plants (59). Its atomic structure has a bearing on its biological essentiality (55), but the limit to which it could be usefully utilised in better crop production requires careful investigation (4). Three distinct lines have been followed to establish its role in plant nutrition : (i) by withholding its supply in culture medium and noting the development of specific deficiency symptoms ; (ii) by supplying the element to the aerial parts through leaf injection or spraying in order to correct deficiency symptoms; and (iii) by supplying the element in small concentrations through the medium in which plants were grown (3). The contributions made by these researches are presented in these pages.

DEFICIENCY OF COPPER AND CROP RESPONSE

Several types of pathological effects due to copper deficiency have been observed. Reclamation disease of cereals is considered to be due to copper deficiency (26) and is characterised by a chlorotic condition of leaf tips and failure to set seeds. Presence of copper in easily available form helps in preventing the disease in wheat, rye, hay grass (51) and other plants (21, 41, 61). This is clearly established by water culture investigations where each addition up to 0.5 mgm per litre of this element improves vegetative vigour, while reproductive vigour is increased only after this critical concentration is reached (6, 7). Characteristic symptoms in cereals are withering and marginal chlorosis (yellowish-grey) of the tips of the younger leaves, which may fail to unroll and a tendency for the foliage to wilt. The bases of the plants remain green and bushy in appearance. Heads are dwarfed, distorted and the tips tend to be chlorotic and undeveloped : grain formation is more severely restricted than vegetative growth. Grains are formed only when a certain critical concentration such as that indicated above is reached. With added supply sterility is gradually overcome (7). In deficient oats, spikelets

suddenly die, accompanied by chloroplast disintegration, lysis of cell contents, collapse of cell collenchyma and internal tissue disorganisation ; but no anatomical differences in cell size and lignification and rate of ascorbic acid loss or protein hydrolysis are noted. Externally, the plants appear as detopped plants (64). In barley, grain formation is checked in complete absence of copper, while traces are helpful in formation of fertile heads and viable seeds (33). In wheat, rye grass, *Phalaris tuberosa*, flax, clover and alfalfa, traces of copper cause marked increase in growth even after the appearance of first deficiency symptoms (42). Significant improvement in yield of wheat (18), cabbage and squash (8), have been obtained when copper is included in the fertilisers applied to certain soils.

Sunflower shows normal blooming and growth when copper is present in traces in solution cultures. Absence suppresses flowering and marked reduction in growth is noted within three weeks. A low concentration of 0.06 mgms. per litre produces a marked growth response. Tomatoes grow normally in such solutions but in concentrations beyond 0.25 mgm. per litre root development is inhibited. Flax also shows improvement in growth but its requirement of copper seems to be higher than that of tomato (54). In a copper deficient medium restricted growth of the leaf of tomato occurs, but the leaflet number and the number of lobes on the leaflets are not reduced. The laminae of leaflets however, remain incurved, develop a bluish-green tinge and show necrotic spots. Internally, the palisade cells contain large hyperchromatic plastids which usually degenerate and form aggregations at one end of the cell. Cavities develop below the stomata and gradually extend throughout the whole length and breadth of leaves, accompanied by lysis of cell contents (46).

In citrus, strong water shoots bearing large leaves with blistered swellings containing gum are formed. These blisters develop into longitudinal ruptures bordered with brown or reddish-brown ridges, from which gum exudation occurs in wet weather. Dieback of the shoot occurs and this is followed by the development of fresh lateral shoots at the base, the latter exhibiting a bunched appearance. Fruits remain small with irregular brownish spots on the skin which split open the desiccation (43). Exanthema in citrus is considered to be due to inadequate copper (23).

In apples, pears, plums, peaches, and apricots, interveinal areas in the leaves show chlorosis accompanied by rosetting of foliage, cessation of apical growth and dieback of branch tips. Apples exhibit chlorosis less frequently but rosette formation is severe followed by dieback of shoot. Pears do not show chlorosis or rosetting but shoot apices and young leaves turn brown and die with no eruptions whatsoever (2). In prunes, exanthema causes vigorous growth of new shoots each spring, but in June terminal buds wither and leaves develop chlorosis ; this is attributed to copper deficiency (43). In plums, bark cracks reaching deep into the cambium exude gum when copper is deficient (53). In deciduous fruit trees suffering from copper deficiency, dipping the shoot apices in 0.2 p.p.m. of copper sulphate solution has been as effective as an application of $\frac{1}{4}$–2 lbs. of this salt per tree in the soil (2).

In all plants investigated so far, application of copper beyond a critical range of concentration invariably results in harmful effects. In general the toxic range of copper varies with the species and the salt used. Thus, in barley, shortening and bunching of roots and other growth variations become apparent in toxic cultures (9), particularly at concentrations just below those which cause marked depression in growth (compare the work reported on rice, oats and other cereals). In paddy, toxic symptoms usually appear when copper concentration is higher than 0.005 p.p.m. in culture solutions (60). In *Nitella*, the cells lose their turgidity as a result of copper toxicity, the toxic effect being proportional to the concentration of copper (14).

Copper Response in Relation to Other Conditions of Nutrition

Response to copper is to a certain extent, related to the availability of other elements, e.g., nitrogen, phosphorus, potassium, iron and aluminium. In peaty soils application of copper sulphate is found beneficial in that growth is improved, together with a reduction in the iron content in the nodes of the corn plant (62). Aluminium in concentrations of 0.1–0.5 p.p.m. shows an outstanding antagonising or detoxifying effect on copper present in traces as impurity in solution cultures and improves growth of citrus seedlings. If copper is entirely absent, such as in purified nutrition solutions, even 0.1 p.p.m. of aluminium depresses growth. The detoxifying influence of aluminium on copper is most marked on the roots where aluminium does not actually prevent copper absorption but somehow prevents the injurious effect of this element on the roots. If aluminium is entirely absent, copper is occasionally absorbed in excess with the result that roots turn brown and produce short swollen laterals forming a dwarf, knotty, unhealthy root system (32).

Copper deficiency symptoms become more serious under medium and high nitrogen applications. These symptoms are overcome by application of potassium salts. Further, copper deficiency is hardly observed in trees grown under low nitrogen conditions : the level of copper applied under these conditions has little effect (60). In high nitrogen trees, low copper fertilisation results in severe deficiency. The nitrogen content of leaves also bears a direct relation to the rate of copper applied but growth hardly seems to be affected by copper. For the normal functioning of leaves, an adequate copper-nitrogen balance is considered essential. Disturbance in this balance during the period of active growth due to insufficient copper or excessive nitrogen usually leads to the development of deficiency symptoms (24).

Absorption of copper is often favoured by decreased pH. Part of the absorbed copper is firmly bound and cannot be removed by leaching (49). Unavailability is frequently associated with high pH of the soil whereby copper is held in insoluble forms (45). Also an increase in acidity for a given level of copper added to the soil, increases the availability of this element (40, 42). In a responsive crop on an acid soil, the effects of copper application may vary from one part of the field to another. A shallow-rooted crop may show more need of copper than a deep-rooted crop if the underlying soil is

less acidic than the upper soil (25). Copper may be rendered completely unavailable under alkaline conditions ; under acidic conditions the degree to which copper deficiency is shown by certain plants may not be merely a matter of H or OH ion concentration but could well be related to the presence of too small amounts of biocatalysts at unfavourable pH values (5).

Copper Manuring of the Soil

Copper is unavailable to many plants in some soils mainly because it is considered to be fixed as humus compounds, the nature of which are still unknown (26). The response produced by this element depends on (i) the amount required by the crop, (ii) the reaction of the surface soil and the underground drained layer, (iii) drainage conditions and (iv) climate. The more acid the organic soils the greater is the relative response to copper and the larger the number of crops that respond to it. The amount of response is also greater in hot dry summer conditions (25).

In soils having an equal percentage of organic matter, the amount of copper removed by extraction with buffered organic acids is found to be proportional to the amount applied. In soils rich in organic matter, only a part of the quantity of copper applied is removed in this way (30). In one instance, application of copper salts has been noted to remove the harmful effects of certain toxins. The particle size of copper sulphate has been noted to affect its solubility in Norfolk sand. In organic soils, copper is held tenaciously in the top few inches (28). Occasionally copper deficiency symptoms are observed in soils rich in organic residues ; these are considered to be due not so much to the formation of insoluble compounds with organic matter but to some physical effects on soil such as those caused by animals grazing (11).

Addition of copper sulphate to slightly acid soils shows that copper is retained near the zone of placement and even after five years the entire quantity is reported to be retained in the upper eight inches of soil (36, 63). Application of Bordeaux mixture at 20 lbs. per acre for thirty years was found to result in an increase of copper to 180 lbs. per acre at the end of this period (52). In another instance, application of 2–10 lbs. of copper sulphate per acre in one season was found to be adequate for several years in as much as succeeding crops showed little or no response to additional application (58). In pastures on peaty soils, five pounds of commercial copper sulphate improved the copper content of grasses and prevented stock diseases. Repeated annual applications of 20 lbs. per acre failed to cause any abnormal increase in copper content of pastures (16). Responses were greatest in peaty (20) and other unproductive soils (1). Applications of copper sulphate increased the chlorophyll content of chlorotic leaves of plants grown in Florida everglade soils (10) and corrected deficiency symptoms of copper in peach trees (27). In fact a small quantity of soluble copper is beneficial to all micro-organisms as well as to the higher plants (38). The critical limit however, depends upon the copper salt used. Copper sulphate shows its optimum effect on the growth of yeast cells when present at a concentration of 7.5 p.p.m. (37) ;

cuprous oxide depresses the growth of yeast when present in amounts greater than 0.0001 gms. per 0.5 gms. of yeast while cupric oxide has no such effect (50).

In Michigan organic soils, responses to copper by different plant species were as follows : (*a*) none to slight: bean, celery, corn, peppermint peas, rape, Rutabagas and spearmint ; (*b*) slight to medium : cabbage, mangel, peardrop, potato, sugarbeet, swisschards, tomato, and turnip ; (*c*) medium to large : barley, carrot, cauliflower, Hungarian millet, oats, sunflower and Table beet ; (*d*) large to very large : lettuce, onion, spinach, wheat and dhil (25). In almost all cases removal of copper from soil by precipitation or otherwise, at unfavourable pH ranges (55) or due to other agencies renders the soil susceptible to reclamation diseases (28).

Copper Content of Plants

Copper sprayed on the leaves in the form of Bordeaux mixture is undoubtedly absorbed and increases chlorophyll content of orange leaves (44). Its absorption is maximal during the active growth period and at seed production. In rice seeds, it is concentrated in the germ to the extent of 1.2–1.3 mgm. per 100 gms. or accumulates in the germ-free hulled rice to the extent of 0.15–0.16 mgm. per 100 gms. (48). The copper content of wheat, oats and barley were within the ranges of 5.6–16.7 ; 6.4–9.8 ; and 6.2–11.9 p.p.m. respectively. The corresponding concentration in the soil has been found to vary from 3.9 to 50.9 p.p.m. of copper with an average of 17.1 p.p.m. Below 6 p.p.m. the correlation between the soil copper content and copper in the grain is appreciable. Moisture shows little influence on copper intake while sterilization by heat increases uptake. Rye absorbs copper more efficiently than oats (42). Copper concentration in the dry matter decreases with increase in the bulk of the plant at later periods in the life cycle. Copper is usually retained in dead leaves and is thus lost to the plant. Copper uptake has been shown to be increased with increasing temperature within limits.

Comparison of the copper content of healthy and deficient plants shows that the latter have only $\frac{1}{4}$–$\frac{1}{2}$ of the content of healthy plants (35). Copper-deficient leaves of pears, for instance, contain 3.1–5.1 p.p.m. of copper as against 11.20 p.p.m. of this element in normal healthy leaves (39). Affected apple leaves have a copper content of 1–3.6 p.p.m. as against 5.5–12 p.p.m. of dry matter in healthy foliage (17). In the majority of plants, insufficient uptake of copper and its immobility in leaves leads to deficiency symptoms even though the soil may contain substantial amounts of this element (64).

Conclusion : Physiological Role of Copper

Copper chiefly accumulates in organs of active metabolism, e.g., seeds, young leaves, sprouts and buds, and has been shown to be a component of certain enzymes particularly oxidases and tyrosinases. It also catalyses chlorophyll formation (44). Its deficiency often causes reduction in the ascorbic acid content of barley, oats and spinach while other crops such as tomato, onions and wheat do not show this effect. Deficient plants are low in carotene content and rich in protein (35).

Even in great dilution, copper inhibits the respiration of yeast, the anaerobic phase being more affected than the aerobic phase (15). The respiration of *Aspergillus niger* remains unaffected by traces of copper for a considerable period (12). This element penetrates the fungus almost immediately but respiration is at first unaffected. A little later, a phase of low respiration begins when copper is active in the cell. Copper is considered to be activated in the respiratory system by means of some reversible reaction (13).

Copper enters into the composition of the oxidising enzyme polyphenol oxidase which contains not less than 0.30 per cent. of this element in the form of a copper protein compound catalysing many vital reactions particularly in potato tubers and cultivated mushrooms (29, 31). The interrelation between copper and zinc in various oxidation-reduction reactions indicates that copper may play such a role in plant metabolism (19, 47, 59). It apparently plays a role in the photosynthetic process since significant reduction in carbon-dioxide assimilation of even apparently normal leaves on deficient plants is recorded (34). It is also considered beneficial in inducing resistance to diseases in the potato (57). Its role in stimulating growth and reproduction may be indirect through its beneficial effects on various plant processes.

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IODINE CONTENT OF FOODS

Annotated Bibliography 1825–1951. *Chilean Iodine Educational Bureau, London,* 1952. *Pp.* vii + 183. *Price* 21 *shillings.*

" The Iodine Content of Foods " is the second volume dealing with the literature of iodine distribution (the first was " Iodine and Plant Life "), and lists 326 papers giving results for 1207 different types of food, arranged in nineteen tables under general headings such as " Milk and Milk Products ", " Vegetables ", and so on. The reader is guided through the list by indexes to authors and foods, a geographical classification and the chronological bibliography. The assembled information is reviewed in an eight-page introduction to the tables.

In its limited field, the book is a masterpiece of tabulation, and might well serve as a model to bibliographers in any subject. The indexing is generous, and the arrangement logical. The subject-matter of the introduction is interesting, but this section is marred by its irritating and redundant style. The defects of the tables are those of the material ; as the compilers note in their preface, too often an analyst gives precise results for the iodine content of a food described only in the most vague terms. Again, on seeking to compare results from different sources, one finds that analysts cannot agree as to whether to express their results in terms of the fresh or dry weight of the substance examined ; surely there is little extra work involved in using both bases ?

The work is attractively arranged and printed, and forms an interesting and useful addition to the literature of the minor elements of nutrition.— K. W. De W.

PESTS AND DISEASES

INSECTS

The Yearbook of Agriculture 1952. *United States Government Printing Office. Pp.* 780. *Illustrated. Price* $2.50 (U.S.)

Most of the leading Entomologists in the United States have contributed to the production of the 1952 Yearbook of Agriculture which is devoted to Insects. This publication is an absolute mine of information and its twenty-one sections, comprising in all one hundred and ten individual chapters, cover the wide field of applied entomology in the unique manner of the Yearbooks.

Introduction to the subject is by way of chapters dealing with the number of species of insects thought to exist, oddities in the insect world, fossil insects, how insects live, their life processes and their method of choosing food-plants. Insect identification and classification receive treatment in a section dealing also with the values of insect collections and the methods of collecting and preserving insects for study. Succeeding sections discuss the role of insects both as helpers and destroyers. The reader is made to realise that, as one author puts it, " insects are not all bad," but the fact that a great many are may be gathered from the amount of space devoted to insecticides, fumigants, quarantines and other controls. The closing sections deal with the pests of cash and food crops, livestock and wild life.

A selected list of publications filling five-and-a-half pages supplements the references given at the end of the majority of chapters. A most useful appendix includes conversion tables and equivalents, a list of definitions and approved names of the many new insecticides now produced in the United States, and a full index.

The book is eminently readable ; the language, striking as it does a happy balance between that of the text book and the popular article, will be acceptable to both scientist and layman.

The pests dealt with are naturally those of greatest importance in the United States, but since most have a much wider distribution, the usefulness of information and recommendations is not confined to American readers. In most cases however pests are not referred to in the text by other than their American common names ; for the scientific names the reader must seek in the index. Although the book is intended primarily for the layman this seems a somewhat unnecessary arrangement, particularly when the scientific names of parasites and crops are liberally supplied. Forming a supplement to the text proper is a selection of the coloured " Picture Sheets ", issued by

the U.S.D.A. Bureau of Entomology and Plant Quarantine, which illustrate the life history of many important insects in the U.S.A. and suggest controls for those which are pests.

The attractive binding, high quality paper, and excellent illustrations and photographs, must make " Insects " at $2.50 (U.S.) one of the best values obtainable in entomological literature published in recent years.—M.H.B.

WITCHES' BROOM DISEASE OF CACAO

(*Marasmius perniciosus* Stahel)

By P. Holliday. *Colonial No.* 286. *H.M.S.O.*, 1952. *Pp.* 8. 16 *Plates. Price* 9*d.*

The Colonial Office foreword to this booklet states :—

" Witches' broom disease of cacao is at present unknown in West Africa and other Colonial territories outside the Caribbean area. It is essential that every effort should be made to avoid the introduction of the disease not only into the important cocoa growing areas in West Africa but also into other areas, such as the Federation of Malaya, Zanzibar and the British Solomon Islands Protectorate, where efforts are being made to establish cocoa growing industries. If the disease unfortunately spreads to any of these territories, it is imperative that it should be recognised as early as possible and that means should be available for dealing with it without delay before it becomes firmly established and virtually endemic.

At the suggestion of the Cocoa Research Sub-Committee of the Committee for Colonial Agricultural, Animal Health and Forestry Research, this booklet, describing the disease and results of investigations carried out at the Imperial College of Tropical Agriculture and financed by a grant from funds made available under the Colonial Development and Welfare Act, has been produced. It is hoped that it will enable agricultural officers concerned with the growing of cocoa to be in a position to recognise the disease and take immediate remedial action if, by mischance, it reaches the areas under their control."

PLANT DISEASES

By F. T. Brooks, 2nd Edition. *Oxford University Press*, 1953. *Pp.* 457. *Price* 38 *shillings.*

It is just twenty-five years since the first edition of this most useful textbook, designed primarily for the use of advanced students in plant pathology, was published. Much progress has been made in this time in the study of plant diseases, and the second edition is, inevitably, a few pages longer than the first. Unfortunately, with rising costs of printing it has almost doubled in price.

One cannot expect a detailed treatment of any disease in a book of this size and one of the great virtues of this book is that the author has not stressed favourite topics of his own to the exclusion of others equally important. The précis and the references given are not always quite up to date, particularly if we consider certain tropical diseases such as the virus and bacterial diseases of sugar-cane, but the student of tropical plant diseases will find far more useful information here than in any comparable book of its size.

Professor Brooks had completed the manuscript of this edition just before his sudden death in March, 1952. It was seen through the press by his colleagues in the Cambridge Botany School—R.E.D.B.

PHOTOSENSITIZATION IN DISEASES OF DOMESTIC CATTLE

By N. T. Clare. *Review Series No.* 3 *of the Commonwealth Bureau of Animal Health. Commonwealth Agricultural Bureaux, Farnham Royal, Bucks.* 1952. *Pp.* 58. 8 *plates. Price* 7*s.* 6*d.* ($1.10 *Can. or U.S.*)

The general practitioner as well as the student will find very useful information in this monograph by Mr. Clare. It is clear, however that this publication will be of more use to the research worker.

A clear cut distinction is made between Photosensitization, Photosensitivity and sun burn, and a plausible explanation of the aetiology of Photosensitivity postulated. The syndromes of Photosensitization in domestic animals are clearly described, and a competent classification of Photosensitivity Diseases given.

There is a comprehensive list of references and a useful appendix listing the names of plants suspected of producing Photosensitivity. Some good illustrations of the Diseases in animals are seen on the few plates.

The monograph is short, concise and easily read.—F.O.G.

PLANT BREEDING

A SUMMARY OF MAIZE BREEDING TECHNIQUES

By

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Introduction

The following review is presented for the use of those tropical agriculturists who, although claiming little specific knowledge of maize breeding, frequently find themselves associated in one capacity or another with maize improvement schemes. To such a person maize improvement is all too frequently, I think, synonymous with the inbred-hybrid breeding technique that has been so successfully practised in the United States during the past quarter century. While the inbred-hybrid method is one which breeders of tropical maize should perhaps work towards as an ultimate goal, it is frequently not the most practical or productive course to follow in the early stages of a maize improvement programme. As will be pointed out later, some of the more simple selection methods are less expensive, produce practical results much more quickly and at the same time tend to concentrate reservoirs of elite germ plasm which can later be used as source material from which to obtain inbred lines.

Hybrid maize has further disadvantages when first introduced into areas whose agriculture still operates at comparatively low levels of efficiency. In such regions few farmers are willing to purchase new seed each year nor are they willing or able in many instances to pay the price required for hybrid seed. Furthermore, the success of a hybrid maize programme depends not only upon the availability of superior varieties but equally important is the manner in which the hybrids are produced and distributed. The building of a dependable organization for production and distribution of hybrid seed is often a task requiring as much or more effort then the initial breeding.

In the discussion which follows several of the more elementary selection methods will be presented first and these in turn followed by a discussion of the relatively recent advances in breeding of hybrid maize.

For a complete and detailed history of maize breeding up to 1946 the reader is referred to a paper by Sprague (1946). This work with its complete bibliography should serve as a particularly useful reference to those workers just entering the field.

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The Importance of Maize Classification in Relation to its Improvement

As a prerequisite to a maize breeding programme in any area it is particularly important, in the writer's opinion, to acquire a detailed knowledge of the types, range of variation and relationships of the material with which one has to work. While technically all maize belongs to a single species, *Zea Mays*, the amount of diversity within the species is enormous and usually within any given country where maize is grown, a few to several distinct races can be recognized. Breeding experience has shown that diversity of origin is of real importance in obtaining maximum hybrid vigour. If the potential benefits of this diversity are to be intelligently exploited in breeding it must be recognized in the beginning rather than mid-way in the breeding programme. Thus a classification of one's materials based preferably on natural relationships should represent the first task of the maize breeder in initiating a new programme.

The matter of the classification of maize is not always as simple as it may appear on the surface. Like most cultivated plants, maize varieties exhibit conspicuous differences in colour of plant, fruit, &c., which though striking in appearance are usually due to a few genes and are therefore not indicative of the distinctness of germ plasm. Much more important in classification are those differences in spikelet shape and venation, spikelet arrangement, rachis morphology, pubescence, leaf shape, internode proportion, row number, kernel length, &c. These characters although difficult to work with genetically because of their multi-factorial inheritance have been found by agrostologists to be significant in the deployment of genera and species. No amount of measurement or scoring of insignificant characters can compensate for failure to select critical morphological criteria for measurement. The former may produce impressive masses of data but it will tell the plant breeder little about the basic differences in the germ plasm of the material with which he is working.

Finally the importance of maintaining a broad genetic base in breeding materials cannot be overemphasized. In many areas this will be supplied by local varieties but if not, it should be supplemented by introductions from other localities, preferably of similar latitude and altitude. In any case one should not limit one's progress by insisting on using local varieties on the theory that anything from the outside is "unadapted". Through hybridization and selection it is often relatively easy to adapt introduced germ plasm to local conditions.

Selection with a Minimum of Inbreeding

Prior to the introduction of hybrid maize, various selection methods were employed by the early breeders in an effort to improve the existing open pollinated varieties. Since these methods have been reviewed by Sprague (1946) and since their use is now largely outmoded it is not necessary to discuss them in detail here. Suffice it to say they included numerous modifications of mass selection, ear to row selection, varietal hybridization, &c. Although the degree of improvement resulting from the

use of such methods was not striking one is not justified in counting these techniques off as failures. Progress was slow and erratic due largely to insufficient parentage control but if the early breeders had accomplished nothing else they provided those workers who were to follow with a large number of heterogeneous varieties of high productive potential which have served as excellent sources of germ plasm from which to obtain inbred lines.

Since maize is predominantly cross-pollinated, parentage control becomes an important factor in determining the degree of improvement to be realized from the use of any selection method. The four methods described below entail some degree of parentage control and should therefore have some advantage over a system involving visual selection of desirable open pollinated plants.

Multiple Top Crosses

This technique, first suggested by P. C. Mangelsdorf, is designed to isolate in minimum time the better segment of open pollinated varieties as revealed in top cross tests. Various modifications of the method have been employed by different workers. In recent years it has been used in Mexico by Wellhausen and Roberts (1949) with considerable success. The method involves a degree of parentage control and any improvement that is realized can be very quickly utilized in a practical way. The breeding procedure is essentially as follows :

1. An adapted agronomically desirable variety (A) is chosen as a parent with which to cross selected lines for testing.
2. A convenient number of selected S_1 lines representing the range of variation of the material at hand are crossed with variety (A).
3. The top crosses (variety A x S_1 lines) are field tested for performance.
4. Outstanding top crosses involving unrelated S_1 lines are crossed with each other resulting in double top crosses. Seed of these hybrids is distributed to growers.

If the S_1 lines represent a wide range of type the use of widely divergent S_1 plants on opposite sides of the double top cross will likely result in considerable variability in the final hybrid. Therefore, if uniformity is important it is necessary to exercise some care in the selection of top crosses to be combined.

Synthetics involving S_1 lines

This is one of the most simple selection techniques which from the theoretical view point should be effective only if dominant favourable growth factors are of primary importance in hybrid vigour. The method has been used by del Valle (1949) in Cuba as a stop gap between unselected open pollinated varieties and hybrids involving inbred lines. The breeding procedure involves :

1. Self pollinate 100–200 ears of desirable plants of one or more varieties.
2. Cross individual S_1 plants with another variety.

3. Compare performance of top crosses in replicated field trials.
4. Using remnant seed combine 20 highest yielding S_1 lines.
5. Increase and maintain synthetic variety by selection of desirable plants.

Although synthetics have been used to only a limited extent commercially they do have in those areas where the annual production of hybrid seed is not feasible or in the early stages of a breeding programme before hybrids are available. In an experiment by Hayes, Rinke, and Tsiang (1944) a synthetic involving eight single crosses and maintained by selection of desirable plants was found to be superior to a standard open pollinated variety and equal in performance to a double cross hybrid, Minhybrid 403.

Recurrent Selection

Some phase of recurrent selection would appear to be among the more promising of those selection methods involving little inbreeding. The method as presented by Hull (1945) proposed the use of an inbred line as a tester for sorting out high combining individual plants among an open pollinated variety, composite or hybrid. In the initial stages of a maize breeding programme where general combining ability is important, the use of a tester with a wider genetic base than that provided by an inbred is certainly desirable. The breeding scheme as adapted to areas where open pollinated varieties only are available might proceed as follows :

1. Self 100 or more plants from a variety or mixture of varieties and simultaneously cross these plants with a tester variety. The tester should be adapted and of above average performance for the area.
2. Compare performance of test crosses in the usual replicated field trials.
3. Select top 10 per cent. of S_1 ears on basis of test cross performance.
4. Plant ear to row selected S_1 ears in breeding nursery and interpollinate or plant in isolated plots and allow to interpollinate.
5. Repeat breeding cycle using crossed seed from (4) above as breeding material.
6. Breeding cycles may be repeated as long as significant improvements are made.
7. Choose the final selected composite x tester for use as commercial seed.

The principal advantage of this technique over those described previously is that it allows for genetic recombinations between desirable genotypes and permits one to continually select the elite germ plasm from the selected interbreeding population. One disadvantage of the method is the amount of time required in carrying through several cycles of breeding. This disadvantage is minimized, however, in tropical environments where two generations of plants can be grown in one year.

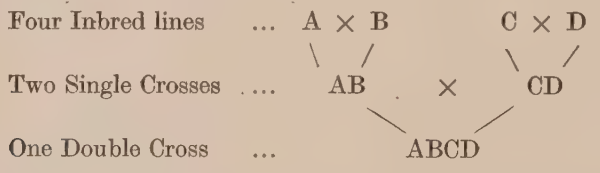
To date there are only limited experimental data comparing the effectiveness of recurrent selection with the usual method of selection among inbred lines. Some of the most critical evidence has been presented by Sprague (1952) and concerns selection for high oil percentage. In this experiment the mean oil percentage of the recurrent series after two cycles was approximately 3 per cent. greater than the mean of the selfed lines after five generations of inbreeding and selection. Likewise the extreme deviate of the recurrent series was about 3 per cent. higher than the two highest oil lines of the selfing series. Whether these results are indicative of what may be expected in selection for more complicated factors like yield and combining ability remains to be determined.

Reciprocal Recurrent Selection

This is merely a modification of the preceding method of breeding in which two varieties or composites, A and B, are simultaneously recurrently selected and tested against each other. The final commercial seed is then produced by crossing selected composite A with selected composite B.

Hybrid Maize

With the exception of sweet corn, most modern maize hybrids are double crosses involving four parental inbred lines. The hybridizations required to produce both the foundation single crosses and final double crosses are effected by planting alternately in isolated fields rows of pollen parents and seed parents, usually in the ratio of 3 females : 1 male. Prior to pollen shedding all tassels of the seed parent plants are removed thereby insuring cross fertilization with the male parents whose tassels are allowed to develop and produce pollen. The series of crosses necessary to produce the final commercial hybrid may be diagrammed as follows :



One cannot of course put together any four inbred lines at random and expect them to result in a satisfactory double cross hybrid. A great deal of selection and testing is necessary in order to isolate desirable double cross combinations. The method, with slight variations usually followed by breeders of hybrid maize is as follows :

1. Isolation of inbred lines by controlled pollination involving selfing or sibbing.
2. Visual selection within and between progenies for desirable plant and ear characteristics.
3. Testing of selected inbreds for general combining ability—top cross or similar test.
4. Testing of single cross combinations of inbreds surviving top cross tests.

5. Predicting double cross performance from single cross data.

6. Testing of double crosses.

It is immediately apparent that the procedure above presents the maize breeder with at least two major problems. The first of these concerns the time at which testing of an inbred should begin and the second is the problem of what to use as a tester.

Among maize breeders there are two schools of thought regarding the stage in the development of an inbred at which testing should begin. One group advocates early testing in which S_1 plants are outcrossed to a tester at the time of first selfing. Performance of the test crosses is then used as a guide to determine whether or not further selfing of the S_0 plant is justified. Proponents of the early testing idea feel that a high percentage of the undesirable lines of a population can be discarded following the first test and before much time and expense is involved in inbreeding and testing.

Those who oppose early testing believe that the performance of an S_0 plant is not indicative of its performance in later generations. They also feel that the inferior genotypes revealed by inbreeding should be ruthlessly eliminated in the early stages of selfing before time, effort, and money have gone into testing.

Experimental data relative to early versus late testing are rather inconsistent and it is perhaps for this reason that most practical breeders follow an intermediate policy of first testing in the S_3 or S_4 generation.

The choice of a tester depends largely upon what is available and what is needed in the particular breeding scheme involved. In a beginning programme where general combining ability is important it is desirable to use a tester possessing a broad genetic base. This may be an open pollinated variety or composite. Once the breeding programme has progressed to the place where specific combinations are desired, then an appropriate tester is needed for detecting specific combining ability. In the American corn belt at present, standard females are widely used as testers. These are single cross hybrids which have proved to be desirable seed parents of commercial double crosses. Their use as testers facilitates the selection of new inbreds which are immediately valuable commercially.

The preceding discussion suggests that maize breeding is still based to a considerable extent on trial and error methods and that because of the amount of testing involved the methods are extremely costly. Because of this, considerable effort has been made in recent years to develop more efficient breeding techniques. In the discussion which follows some of those methods are briefly described :

Recurrent and Reciprocal Recurrent Selection

This system of breeding was described under "Selection with a Minimum of Inbreeding". It needs no further elaboration here except to point out that in a hybrid maize programme the final products resulting from recurrent selection may themselves be used as improved varieties or as source material

for the isolation of inbred lines. Likewise at any stage during the selection process, S_1 lines of outstanding performance can be removed from the composite and subjected to further inbreeding. Also the utilisation of recurrent selection in an advanced breeding programme would probably involve the use of a more specific tester than that described previously.

Gamete Selection

The breeding system proposed by Stadler (1944) is based on gametic rather than zygotic selection. If in any population of plants zygotes of a particular combining ability occur with a frequency of 1 per cent. then gametes of similar combining ability should occur with a frequency of 10 per cent. If superior gametes can be recognised with certainty such a system should then theoretically be ten times as efficient as one based on zygote selection. The breeding procedure as originally proposed involves first the crossing of plants of a potentially useful variety with a homozygous inbred line. The resulting population consists of plants each of which has one gamete in common (that from the inbred line) in combination with a sample gamete from the variety. If a sufficient number of crosses is made the resulting hybrid plants should embody a representative sample of the varietal gametes. Each plant resulting from the first cross is selfed and simultaneously outcrossed to a tester. At the same time the original inbred line is crossed with the same tester. All test crosses are then compared for yielding ability and any variety x tester combination that is significantly superior to the inbred x tester cross is assumed to involve a varietal gamete that is superior to that contributed by the inbred line.

Isolation and Utilization of Monoploids

In maize, reproduction is usually by normal sexual means in which a male gamete bearing 10 chromosomes unites with a 10 chromosome egg. The union results in the normal 20 chromosome zygote. However it has been found that occasionally a sporophyte is produced without the benefit of previous fertilization. These have been termed monoploids by Chase (1949) and although the percentage frequency of this occurrence varies with different kinds of maize, monoploids appear approximately once in every 1,000 plants. Such plants can be readily isolated in the seed and seedling stage by the use of appropriate genetic tests. If following isolation the chromosome number of these plants can be successfully doubled the resulting plants should be, barring mutations, completely homozygous. Thus it is posssible through the use of this technique to produce completely homozygous inbred lines in one generation as compared with the 6–10 generations ordinarily required by self-fertilization methods.

The performance of homozygous diploids developed from monoploids has not yet been critically compared with lines of similar genetic background produced in the normal fashion. The data that are available, however, would suggest that the method has some promise in those programmes where inbreds are needed quickly. In long established breeding programmes the main problem concerns not the lack of inbreds but facilities for and method of testing those that are available.

Monoploids may be of value in connection with gamete selection. By the application of this selection method to monoploid derivatives one could actually test gametes *per se* instead of having to test gametes in combination with a tester as is now done.

Cytoplasmic Male Sterility

In the production of hybrid maize on a commercial scale the large number of controlled hybridizations necessary is brought about by the planting of pollen and seed parents in the same field followed by the detasseling of each seed parent plant. The method although workable has some disadvantages. In the first place it is expensive. At present U.S. wage levels the manual removal of tassels from the seed parents results in a cost of approximately seventy-five cents (5*s.* 3*d.*) per bushel of seed. Secondly it necessitates the dependence upon a large supply of seasonal labour which must be recruited, housed, fed and trained.

As a means of eliminating manual detasseling the progress that has recently been made in the application of cytoplasmic male sterility appears promising. Many genes for male sterility have been investigated in maize. These are all recessive and they vary considerably in the degree of sterility expressed in the homozygous conditions. Unfortunately none of these genes are closely enough linked with other characteristics to make possible the positive selection of homozygous *msms* seeds in a segregating population. In addition to the genetic factors for male sterility there is a male sterile character whose inheritance is cytoplasmic and which from a practical viewpoint is much more promising than the genetic male steriles. Cytoplasmic male sterility was first described by Rhoades (1933) and more recently has been investigated by Jones (1950) and Rogers (1952). This particular characteristic is apparently fairly common in maize although the different known forms vary in potency and in the degree to which they are modified by a given genetic background.

Since the factor is cytoplasmic, transmission takes place through the egg only. The breeding procedure in producing male sterile inbreds involves a series of backcrosses following the original cross and is essentially as follows: the cytosterile source (S) is used as a seed parent in outcrosses to a series of inbred lines, A, B, C, &c., each of which is eventually to be used on the female side of double crosses. (S) A, (S) B, &c., are backcrossed to the male fertile inbreds a sufficient number of times to recover the genotypes of the original inbred lines. Following a sufficient number of backcrosses the recovered lines will differ from the originals only by reason of their being male sterile. In subsequent generations the male sterile lines are maintained and increased by crossing with their normal fertile counterparts.

In production a male sterile inbred is used as a female in crosses with a male fertile line to produce a commercial seed parent single cross. The resulting seeds will produce male sterile F_1 plants which are subsequently used as seed parents in hybridizations with normal single crosses to produce final commercial double cross hybrids. As a double cross so produced will

itself be pollen sterile, some means of overcoming this sterility in the final hybrid is necessary. This may be accomplished in one of two ways, (*a*), by blending seed of the pollen sterile double cross with a quantity of normally produced seed of identical parentage or, (*b*), using as a pollen parent of the double cross, a single cross capable of restoring fertility to the otherwise male sterile hybrid. At present the former method is that most generally used but it will likely be replaced by the latter as better " pollen restorers " become available.

The Use of Morphological Criteria in Predicting Combining Ability

One of the primary limiting factors in maize breeding is the amount of testing required to separate elite inbred lines from those of average or inferior performance. Any method which would aid in screening out undesirable inbreds prior to testing would be of value. For this purpose the use of morphological criteria may have some promise. A case in point concerns maize of the United States corn belt for which it has been proved historically cytologically, and genetically that the open pollinated varieties which preceded hybrid corn were produced by the deliberate mixing over a period of a century or more of two distinct races of maize, the northern flints and the southern dents.

If in modern corn belt inbreds the germ plasm of these two races of maize is still partially intact as a result of linkage, as indeed it appears to be, it should be possible to classify such inbreds on the basis of morphological differences according to flint and dent tendencies. If such a classification reflects genetic diversity and if genetic diversity is important in bringing about a heterotic effort in hybrids, one should be able to predict with some accuracy the relative degree of heterosis to be expected from crossing any two inbred lines. A series of experiments to test this hypothesis has been conducted by the author during the past several years. Typical of these experiments is one involving some fifty inbred lines. Each of these lines was scored for row number, kernel length, denting, development of husk leaf blades, number of secondary tassel branches, glume length and chromosome knob numbers. For each of these characteristics the two extremes in the corn belt are to be found in the northern flints and southern dents. Mean scores of each of the inbreds were translated into numerical index values in which a low value represented northern flint-like tendencies and a high value southern dent-like tendencies. One hundred single cross combinations were made of the inbreds and these were tested for yielding capacity in replicated field trials.

Correlation coefficients between yields of the F_1 hybrids and index differences of the parental inbreds of each of these hybrids were then calculated. Results from two years' data gave correlation coefficients of $r = +0.40$. This figure although highly significant statistically is not of sufficient magnitude to be of much value for predictive purposes. Its significance does suggest, however, that with refinements in scoring and with proper weighting of the characteristics used the method may have some practical application in breeding.

The Importance of Linkage in Maize Breeding

The effects of genetic linkage on maize improvement have probably not received attention commensurate with their importance. The experimental data available, Anderson (1939), indicate that in interspecific or interracial crosses, many of the multiple factor characters which characterize each species or race are linked and tend to remain so even after generations of breeding. Supporting evidence for this has been demonstrated in the maize of the U.S. corn belt, Brown (1949), in which in spite of many generations of mixing, characters of each of the two putative parents of corn belt maize tend to be associated even in modern dent corn inbreds. These facts are of particular significance to the maize breeder since one of his major problems is that of breaking linkages. And the problem is a particularly critical one in those programmes in which genetic recombinations are sought between crosses of distinct types or races. A procedure frequently followed in such cases is one involving selfing or sibbing of desirable individual plants in the F_1 and succeeding generations of the cross. Such a procedure, it seems, permits the recovery of slightly modified parental types and little else. The limited data that are available, Brown (unpublished), suggest that a minimum of four or five generations of interbreeding is necessary before one can expect to obtain major recombinations out of crosses between distinct races. These facts probably have particular application to recurrent selection and similar schemes in which progress is a direct function of the degree of genetic recombination occurring in the breeding population.

Summary

1. The value of maize classification in a breeding programme and the major problems involved in classification are discussed briefly.

2. Several simple selection methods are described. It is suggested that in the early stages of an improvement programme certain of these techniques might be more practical than the inbred-hybrid method of breeding.

3. Recent modifications in hybrid maize breeding methods are discussed.

4. It is suggested that the effects of linkage in maize should be given particular consideration in those breeding schemes designed to utilise genetic recombinations between diverse races.

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COMMUNICATIONS ON ORIGINAL INVESTIGATIONS

THE CONTROL OF SUGAR-CANE MOTH BORERS (*DIATRAEA*) IN VENEZUELA—A PRELIMINARY ACCOUNT

BY

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THE growing of sugar-cane in Venezuela dates from early Spanish colonial times, at least three hundred years ago, and the crop has always ranked among the country's major agricultural resources. While small areas of sugar-cane are to be found scattered throughout the whole territory, the principal centres of commercial production at the present time are located in the northern States of Sucre, Miranda, Aragua, Carabobo, Yaracuy, Lara, Trujillo, Zulia, Mérida and Táchira, with an altitudinal range from sea-level to 6,000 feet, though mostly at elevations of 950–2,100 feet. They may be thought of as an archipelago of ecological islands lying within a curved belt about 60–100 miles wide, stretching across the country from east to west for a distance of nearly 600 miles. The area under cane cultivation by estates (*haciendas*), for the production of sugar and *papelon* on a commercial scale, aggregates approximately 80,000 acres, with an all round average yield which may be estimated at between 25 and 30 long tons of canes per acre. Excellent yields of cane, often in excess of 65 tons per acre, however, are frequently obtained on some of the best properties, and where proper scientific control of the land is in practice fields are harvested yielding 70–75 tons per acre as plants, followed by 45–50 as ratoons. The crop period varies from place to place according to local climatic conditions, but usually plant fields are harvested at 14–16 months, and ratoons at 12–14 months. Long ratooning is not the practice, and normally fields are replanted after 2–3 successive harvests. The quality of extracted juice varies greatly, and while a ratio of 8 per cent. sucrose in cane is not considered unsatisfactory, yields of 12 per cent. or more are also obtained. Heavy moth borer infestation has been one of the limiting factors in this direction. The general agricultural conditions, with notes on climate and with special reference to the soils, in the principal cane-growing regions, have been described in a series of agronomic studies by R. V. Peña, S. J. Strebin and their associates, published by the Division of Soils of the National Institute of Agriculture (1947–1951). A considerable number of cane varieties old and new are to be found on the *haciendas*, but those most generally cultivated are the *P.O.J.* 2878 and other *P.O.J.* varieties, *B.H.* 10 (12), and some of the *Coimbatore* canes ; more recently the *B.* 37161 has come into favour on some of the more progressive properties. Irrigation is the rule rather than the exception, and there is a tendency for some planters to apply far more water than is required for the healthy growth of the plant, especially as it is nearing maturity. Within the last few years modern

centrals, capable of milling up to 2,500 tons canes per day, have been erected, for the production of refined sugar, replacing groups of small old-time muscovado mills operated by water-wheels, animal power or diesel engines, in several of the larger cane-growing regions. Production is still far below the country's requirements, and large quantities—more than 55,000 tons annually—of raw sugar are imported, mostly from Cuba. The cost of sugar products in Venezuela, whether locally produced or imported, is very high when compared with other countries. Cane is bought by the factories at from Bs.45.00 to Bs.50.00 (£4.10–£5.0) per ton (1,000 kilograms). Refined sugar, as well as *papelon*, retails in the towns at approximately Bs.1.10 per kilogram (1*s*. $1\frac{1}{2}$*d*. per lb.).

A general outline of the sugar-cane entomology was recently published by the writer (4), and a list of all insects known to feed on sugar-cane in Venezuela was presented at the 8th Congress of the International Society of Sugar Cane Technologists held in the British West Indies, April, 1953, and will be printed in the Proceedings (8).

The most important insect pests of sugar-cane in Venezuela are the "small moth borers" (*Diatraea*). Since November, 1946 they have been under continuous study by the writer and his staff in the Division of Entomology of the Ministry of Agriculture, with headquarters at the National Institute of Agriculture, Maracay, Aragua State. It was already recognised that several species of *Diatraea* of economic importance occur in Venezuela in addition to the well-known *D. saccharalis*, but until the present investigations began these had not been properly identified and consequently their geographical and ecological distribution within the country were largely unknown. Detailed accounts of these investigations have been published by the Ministry as technical bulletins of the Institute (1, 3, 7). A taxonomic study of the species involved has also been published (6).

Among the fourteen species of *Diatraea* now known to occur in Venezuela (6), the following are of economic importance to the sugar industry :

D. saccharalis (F.)—Widely distributed. A major pest in Miranda, Aragua, Yaracuy, Lara, Mérida and Táchira.

D. impersonatella (Wlk.)—Widely distributed as a borer in *Paspalum* spp., but as a pest of sugar-cane has been found only at Cumanacoa and Cumaná (Sucre) and the El Tocuyo valley (Lara).

D. canella Hmps.—Widely distributed. Principally a pest causing "dead-heart" injury in young shoots, especially in fields of ratoons ; seldom responsible for serious damage in jointed canes.

D. busckella busckella Dyar & Heinr.—A major pest in western Yaracuy, Lara, Trujillo, Zulia, Mérida and Táchira.

D. rosa Heinr.—A major pest in Sucre, Miranda, Aragua, Carabobo and eastern Yaracuy. Endemic in Venezuela.

The peculiar geographical distribution of *D. busckella* Dyar & Heinr. (represented in Venezuela by several sub-species and forms) and the closely related *D. rosa* Heinr., is discussed in detail in the writer's publications.

The maize borer, *D. li eolata* (Wlk.) occurs throughout Venezuela, and maize is also attacked by *D. saccharalis* as well as *D. rosa*.

Complete lists of the alternative food-plants, and of all parasites of *Diatraea* known in Venezuela, are given as appendices in the writer's most recent report (7). Among the Dipterous parasites, the dexiine *Paratheresia claripalpis* (Wulp) is the most important. It attacks practically all of the larger *Diatraea* species, but does not appear to exert any marked control over the sugar-cane borers except possibly in the eastern cane area of Cumanacoa (Sucre), where it is probably responsible for the general low infestation. The Venezuelan race of *P. claripalpis* (designated *PV*) differs from that of Trinidad (*PT*) in that it is particularly effective as a parasite of *D. lineolata* in maize. The race *PT*, on the contrary, seldom attacks this host in the field, and very rarely in laboratory tests, so that larvae of *D. lineolata* are unsuitable as hosts for the *PT* race in rearing work. A hybrid race, $PV \times T$, was produced at Maracay, which could be reared on *D. lineolata*, but much less successfully than the native *PV*. Another dexiine, *Leskiopalpus diadema* (Wied.), is of wide distribution as an occasional parasite of various *Diatraea* species in sugar-cane and wild grasses ; it is most frequently found attacking *D. saccharalis* and *D. busckella busckella* in the Rio Turbio valley, near Barquisimeto. Two other native tachinids, viz. *Palpozenillia palpalis* (Aldr.) and *Jaynesleskia jaynesi* (Aldr.), have been reared from *D. canella*, the former in sugar-cane (rare) and the latter in a savannah grass, *Andropogon bicornis* L.; *J. jaynesi* has also been reared from *D. impersonatella* in *Paspalum paniculatum* L. Hymenopterous parasites of the sugar-cane borers include *Ipobracon grenadensis* Ashm., and two *Ipobracon* spp. not yet identified, *Agathis sacchari* (Myers), *A. stigmatera* (Cress.), "*Spilocryptus*" sp. nov., and *Spilochalcis dux* Wlk., but their combined effect is negligible as a factor in natural control.

Moth borer infestation varies considerably in the different cane-growing regions, depending not only on local climatic and other conditions but also on the species of *Diatraea* present, some of these being more destructive than others.

The normal average Intensity (per cent. of joints in mature canes showing external injury) in the most important sugar-cane areas (listed from east to west), calculated from 371 examinations made during five consecutive harvesting periods (1946–47 to 1950–51, inclusive), is as follows :

Sucre : Cumanacoa (alt. 750 ft.) (*D. rosa, D. impersonatella*)	6.0%
Miranda : Santa Lucia and Ocumare del Tuy (alt. 575–850 ft.) (*D. rosa, D. saccharalis*)	12.0%
Aragua : Aragua and Upper Rio Tuy valleys (alt. 1,450–1,750 ft.) (*D. rosa, D. saccharalis*)	16.0%
Carabobo : Central Tacarigua (alt. 1,375 ft.) (*D. rosa* only) ...	11.5%

Yaracuy: San Felipe (alt. 350–450 ft.) (*D. saccharalis* only)* less than 5.0%

Chivacoa (alt. 705 ft.) (*D. busckella busckella, D. saccharalis*) 10.5%

Yaracuy & Lara : Rio Turbio valley (alt. 1,200–1,400 ft.) (*D. busckella busckella, D. saccharalis*) 17.5%

Lara : El Tocuyo valley (alt. 1,900–2,750 ft.) (*D. busckella busckella, D. saccharalis, D. impersonatella*) 26.0%

Trujillo : Valera-Motatán (alt. 1,150–1,800 ft.) (*D. busckella busckella* only) 15.0%

Mérida : Mérida-Egido (alt. 3,250–6,000 ft.) (*D. saccharalis, D. busckella busckella*) 10.5%

Táchira : San Cristóbal, Rubio, Ureña (alt. 1,150–2,500 ft.) (*D. busckella busckella, D. saccharalis*) 17.5%

The destructiveness of two of the native borers (*D. busckella busckella* and *D. rosa*), and the high value of sugar products, cause the losses from *Diatraea* damage in Venezuela to be proportionately much higher than they are in other countries, where *D. saccharalis* only has to be contended with. These losses (in the field and factory combined) were estimated in 1947 to amount to approximately Bs. 18 million (approximately £1,800,000) annually.

The object of the intensive field investigations carried out during 1947–1950 was to survey the ground and to lay the foundations for a planned campaign of biological control. It was not expected that any single introduced parasite would attack all the different kinds of sugar-cane moth borers, and therefore it was considered imperative to determine the exact distribution of each of these as well as its actual status in different localities. Experiments were also conducted to determine the host preferences of the local (*PV*) race of *Paratheresia claripalpis*, since the importation of foreign races of this dexiine was to be included in the programme. The general results of all this preliminary work have been published in the writer's reports, and the main features have been summarised in the foregoing paragraphs.

In the light of experience gained elsewhere, the writer recommended that the most promising parasite for first trial under Venezuelan conditions would be the "Amazon Fly" *Metagonistylum minense* Tns., to be followed if necessary by introductions of the "Cuban Fly", *Lixophaga diatraeae* (Tns.). The normal host of *Metagonistylum* is *D. saccharalis*, and the known natural range of this tachinid covers an enormous triangle on the South American continent, the points of which are Santarem and Iquitos, 1,300 miles distant from each other on the River Amazon, and São Paulo, about 1,500 miles to

* At San Felipe the infestation has been examined each year at one *hacienda* where, apart from occasional *D. canella* in young ratoons, it was due entirely to *D. saccharalis*, but the Intensity was always so low that actual joint counts were not necessary. Recently, however, *D. busckella busckella* has gained entry to this area, undoubtedly in infested seed-cane injudiciously brought from the Rio Turbio valley in 1950. The infestation in February 1953, was much higher than at any time before, and samples of borers showed 63 per cent. to be *D. busckella busckella*. Actual counts of harvested canes showed an Intensity of 10.0 per cent.

the South. The form occurring at São Paulo is considered to be a race distinct from the Amazonian and supposed to be better adapted to conditions of low rainfall. The Amazonian race has been introduced and become permanently established in the canefields of British Guiana and the island of St. Lucia, B.W.I., and has also shown promise of success in Puerto Rico and Louisiana, where trials with the São Paulo race (as well as hybrids between the two) were made by the entomologists of the United States Department of Agriculture. For some reason difficult to comprehend this parasite seems to have failed each time that it has been tried in Trinidad. Whilst highly specific to *D. saccharalis* in its original habitat, *Metagonistylum* attacks a small percentage of the larvae of *D. canella* in British Guiana and St. Lucia, and it is known to be rearable on *D. impersonatella* under laboratory conditions in Trinidad. It was a matter of conjecture, however, what would be its reaction on the native Venezuelan borers, especially the large larvae of *D. rosa*. The programme therefore called for immediate tests to determine to what degree the Amazon Fly would parasitize the various sugar-cane borers in Venezuela, first in the laboratory and later in the field. Simultaneously with the introduction of this parasite it was also arranged to make similar trials with foreign races of *Paratheresia* commencing with the one peculiar to Trinidad.

The campaign, since the commencement of the investigational work with the writer's appointment in November, 1946, has been financed entirely by the Ministry of Agriculture. Its total cost, including salaries, transportation, purchase of parasites, and all running expenses during the six years (to end of 1952) has been rather less than Bs. 500,000 (£50,000).

Details of the actual importations are given in the writer's most recent report (7), and here it is sufficient to state that the first lots of 750 puparia of *Metagonistylum* and 300 puparia of *Paratheresia* (*PT*) were received in October, 1950 ; these were supplied by the Commonwealth Bureau of Biological Control, Trinidad*. During the period May-August 1951, a further 20,350 *Metagonistylum* and 4,450 *P.T.* were obtained from Trinidad. In August a consignment of 100 puparia of the São Paulo race of *Metagonistylum* was kindly sent to Maracay by Mr. L. C. Scaramuzza, who has recently received them at his laboratory at Mercedes, Cuba. In July, 250 puparia of *Paratheresia* were received from Mexico, and in November Mr. Scaramuzza sent 50 from Peru. Throughout the whole period additional flies were continually being reared at the Maracay laboratory, partly for purely experimental work but also to increase the numbers available for liberation. To the end of 1951 a further 5,145 *Metagonistylum* and 4,133 *Paratheresia* were thus produced. Experimental work practically ceased early in 1952, but production has continued at the Maracay laboratory, with Señor P. Paredes R. in charge ; during 1952 he reared approximately 12,000 *Metagonistylum* mostly of the São Paulo race, for liberation in the canefields.

* The stock of *Metagonistylum* available in Trinidad had been obtained by Dr. F. J. Simmonds from St. Lucia, and was therefore the direct progeny of Myers' original introductions from the Amazon into British Guiana in 1933. St. Lucia was colonized from some 200 puparia received by the present writer from Mr. L. D. Cleare, who sent them from Georgetown in November 1934.

Detailed results of the laboratory experiments are on record (7). Both races of *Metagonistylum* could be readily bred on the larvae of *D. busckella busckella* and *D. rosa*, and these borers proved to be excellent hosts, supplementing field collected *D. saccharalis*, for the Scaramuzza-Box technique of mass rearing. Positive results were also obtained by artificially inoculating larvae of *D. busckella setariae* Box and *D. pedibarbata* Dyar, but negative always when *D. canella* was used.

A summary of the effects upon different *Diatraea* species, using different races of *Paratheresia*, may be extracted from the cited publication. The comparisons are based on the percentage of complete parasitism resulting from an adequate number of larvae (not less than 100) inoculated, according to the following arbitrary grouping (a dash indicating that insufficient or no trials were made) :

Parasitism high (49.0 per cent. or more)	+++
Parasitism medium (24.0 per cent.- 43.5 per cent.) ...	++
Parasitism low (6.4 per cent.-13.0 per cent.)	+

Race of *Paratheresia*	Species of *Diatraea* Inoculated			
	saccharalis	*rosa*	*b. busckella*	*lineolata*
P. Venez. (*PV*)	++	+	—	+++
P. Trinidad (*PT*) ...	+++	++	—	+
P. Venez. x Trin. (*PV* x *T*)	++	++	++	++
P. Mexico (*PM*) ...	+++	+++	—	—
P. Mex. x Trin. (*PM* x *T*)	++	+++	—	+
P. Peru (*PP*)	+++	+++	+++	+

Based on the above, certain general conclusions were formulated :

(i) Parasitism by the race *PV* is outstandingly superior, whereas with *PT* it is clearly inferior, when *lineolata* is used as the host, thereby confirming field observations in Venezuela and Trinidad, respectively. The race *PP* behaves similarly to *PT* ; *PM* tends to behave as *PV*.

(ii) There is evidence that the ability to parasitize *lineolata* to a high degree, may be hereditary, and that when *PV* or *PM* (which also prefers *lineolata*) are hybridized with *PT*, the resulting crosses (*PV* x *T*, *PM* x *T*) show a pronounced reduction in this ability.

(iii) The three imported races (*PT*, *PM*, *PP*) are superior to the native race (*PV*) in respect to parasitism of *saccharalis*, but when "diluted" by hybridization with *PV* they tend to lose their superiority.

(iv) The hybrid *P V* x *T* (which has been reared through numerous successive generations), seems to be of more practical value, though

not proven actually superior (in laboratory experiments), than either of its parents, as a parasite for general conditions in Venezuela.

(v) Both the *PM* and *PP* races showed a marked preference for *rosa* as a host in the laboratory, and the *PP* also for *busckella*.

It was noted that matings between the sexes were much more readily obtained with the *PP* than with any of the other races tried, and this race seems to be the best adapted for artificial multiplication in the laboratory.

Repeated liberations, totalling 5,005 *Paratheresia* flies (of which 1,813 were females, mostly mated), consisting of all the races and hybrids specified above, but mostly *PT* and *PV* x *T*, were made at several *haciendas* in the Aragua valley (Aragua) and at Central Tacarigua (Carabobo) from March to December 1951. A further 341 (161 females), all *PT* and *PV* x *T*, were released at two *haciendas* in the El Tocuyo valley (Lara) in December. Records had shown that this dexiine was rare as a parasite of sugar-cane borers in this last locality, and it was hoped to improve the situation by these liberations. Plans were made for an elaborate campaign during 1952-53 using the Peruvian and Mexican races (*PP*, *PM*), which it was thought might be better adapted to the dry surroundings of El Tocuyo, but the rapid establishment there of the Amazon Fly has made this measure unnecessary.

Proof of establishment of these foreign races of *Paratheresia* is difficult to obtain, since they cannot be distinguished as larvae or adults from the indigenous *PV*. It was accepted, however, on general principles, that nothing but good could follow their liberation, if only as a means to improve the efficiency of the latter. At the close of the 1951 campaign the writer stated that " Certain unprecedented increases in natural populations of *Paratheresia*, in localities where introduced races and laboratory-produced hybrids had been liberated, are probably attributable to the successful but temporary establishment of these foreign races". No further evidence of success with the imported *Paratheresia* was forthcoming until the writer's visit to El Tocuyo in February, 1953, when flourishing colonies were discovered attacking chiefly *D. saccharalis*, but also occasional *D. busckella busckella*, at two *haciendas* in a part of the valley where this parasite had not previously been found, in spite of annual surveys. In one of these *haciendas*, viz. El Molino (alt. 2,050 ft.), current parasitism in a small sample from a scarce population of *D. saccharalis* collected in young plant cane on 6/2/53 amounted to 3/16 (19 per cent.) (with a similar figure for *Metagonistylum*). We are therefore satisfied that the introduction of foreign races of *Paratheresia* has not proven a failure in Venezuela, at least in this region.

The remainder of this paper deals with the Amazon Fly campaign, and no further reference need be made to *D. canella* since this borer has never been found parasitized by *Metagonistylum* in Venezuela, and all attempts to rear the parasite upon it have resulted in failure.

The earliest liberations (October 1950, onwards) were of the Amazonian race, but later (from October 1951) this was gradually supplanted by the São Paulo race, a small initial stock of which was received from Mr. Scaramuzza in Cuba and has been maintained, generation by generation, ever since. It is extremely probable that as the campaign proceeded we were using more and more "hybrids" between these races, because the laboratory stock was continually being replenished by small numbers of field-collected puparia. No further distinction between them, therefore, is necessary in the account that follows.

Except for certain *haciendas* in Guárico, Miranda, Carabobo and Trujillo, which were colonized in 1951 (some of them three times successively) but which did not receive continuous reinforcements, and where up to the present no apparent results have accrued, the main campaign was directed to colonizing the important cane-growing regions in Aragua and Lara, especially the valley of El Tocuyo, where the *Diatraea* infestation was highest. Once it was known that *Metagonistylum* could readily be reared on species of *Diatraea* other than *D. saccharalis*, we felt justified in adopting this course of action, fully recognising the uncertainty of getting results under field conditions. Included for a special reason, however, was the small Hacienda La Marroquina, situated at 350–400 ft. elevation in a clearing in the evergreen rain-forest zone bordering the Rio Yaracuy a few miles south of San Felipe (Yaracuy). Apart from a normally very low borer population (all *D. saccharalis* until 1952) in the canefields, it was believed that the conditions of the habitat were ideal for the establishment of the Amazon Fly, including beds of aquatic grasses (chiefly *Panicum grande* Hitchc.) which harbour larvae of *D. saccharalis*, on the river banks. Excluding this small area (less than 200 acres under sugar-cane), which may be considered "experimental", the *haciendas* requiring adequate colonization, to determine on a plantation scale the success or otherwise of the Amazon Fly introduction, amounted to something like 35,000 acres, divided between the important cane producing regions in the Upper Rio Tuy and Aragua valleys (Aragua), the Rio Turbio valley (Lara), and El Tocuyo (Lara). The *haciendas* in Aragua are accessible in less than an hour from headquarters at Maracay, but to reach those in Lara a whole day's journey by car was usually necessary. The more distant regions of Sucre in the East, Mérida, Táchira and Zulia in the West, were not included in the first year's campaign because of the difficulties of long-distance transport. The method of packing the flies (or sometimes puparia) for transportation to the *haciendas* is described and illustrated in Technical Bulletin No. 5 (7).

The procedure was to make liberations, as far as possible at fixed intervals (corresponding to the duration of one or two generations), of colonies of adult flies, each colony including from 30 to 60 females and generally many more. The females, prior to release, were confined in cages at the laboratory with numerous males, for 5-6 days, so as to ensure a high percentage of them being fertilized and nearly ready to commence larviposition. According to the circumstances the actual numbers of fertile females liberated varied greatly, but there is strong evidence that the best results followed where colonies of

several hundred at a time were originally released, followed by systematic liberations of smaller numbers at frequent intervals. Care was given to the selection of suitable fields in which to liberate flies, and it was soon learned that the best results would be obtained in fields of young unjointed shoots, provided that they contained a reasonable proportion of suitable borers. Plant fields were to be preferred because of the predominance of *D. canella* in young ratoons. During part of the dry season of 1951, when there was a heavy mortality among flies confined in cages at the Maracay laboratory, the puparia were distributed to the *haciendas*. These were placed, 500 or so at a time, in special ant- and weather-proof receptacles designed for the purpose. By examination of the residual puparia later, it was found that there had been a minimum of mortality among them, but of course it was not possible to know what proportion of the emerging flies succeeded in mating and in surviving the 8–9 day period of gestation.

Numbers of *Metagonistylum* (females) liberated in Aragua, Yaracuy and Lara, 1950–51 and 1952

	1950 (Oct.-Dec.) and 1951 (Jan.-Dec.)	1952 (Jan.-Dec.)
Aragua :		
Upper Rio Tuy & Aragua valleys (alt. 1,450–1,750 ft.)	841	1,016
Yaracuy :		
San Felipe : Hacienda La Marroquina (alt. 350–400 ft.)	222	60
Yaracuy & Lara :		
El Turbio valley (alt. 1,200–1,400 ft.) ...	705 (+3,860 puparia)	681
Lara :		
El Tocuyo valley (alt. 1,900–2,750 ft.) ...	630 (+3,000 puparia)	3,296

During the first year of the campaign examinations were frequently made in the areas which had been colonized with the flies, to ascertain if there was any degree of establishment, but with two notable exceptions the general results at the end of 1951 were not very encouraging.

Before describing the results of the general survey made in January-February 1953, it may be of interest to record the early days of the establishment of *Metagonistylum* in Venezuela. Significant recoveries were made in 1951 only at two localities, one in the Aragua Valley and the other near San Felipe (Yaracuy).

The first recovery of the Amazon Fly was made in January 1951, at the Hacienda Tucupido, a comparatively small property in the foot-hills N.-E. of Maracay (alt. 1,450 ft.), completely isolated from the main sugar-cane areas of Aragua. A total of 226 females had been liberated there since October 1950, in seven separate colonizations. On 20/1/51 a freshly formed puparium of *Metagonistylum* was found alongside larval remains of *D. rosa* in

a field of jointed cane about 8 months old. Despite repeated searches no further parasites were found on the *hacienda* until September, and because it was desired to test the permanency of the " established " colony no further liberations were made after January. On 19, 20 & 25/9/51 a total of 11 puparia were recovered from nine parasitized hosts (4 *rosa*, 5 *saccharalis*) collected from three fields, two of which were of young plant canes which of course had not been colonized. Borers were hard to find at this time, but parasitism by *Metagonistylum* amounted to one-third of a small sample (21) of *rosa* and *saccharalis* taken from one field. This established colony was of the Amazonian race, but in September 36 females of the São Paulo race were liberated. No recoveries were made in any other *hacienda* in the Aragua valleys during 1951. The liberation of flies continued in the main part of the Aragua valleys, and there was a gradual improvement in the situation in 1952. At any time of the year the introduced parasite could be found in almost any field at the Hacienda Tucupido, though it was becoming more and more difficult to find sufficient " dead-hearts " in young fields for a sample ; elsewhere in the valley occasional parasitized borers (but seldom more than one at a time) and emerged puparia were found on some of the *haciendas*. It may be mentioned that the " general ecological conditions " of the Hacienda Tucupido differ in no marked respect from those of the rest of the region. They are, however, in complete contrast to those prevailing in the tropical rain-forest zone of the Rio Yaracuy valley, where the other area of early establishment of *Metagonistylum* is situated. As already stated, the Hacienda La Marroquina, near San Felipe (Yaracuy ; alt. 350–400 ft.) was chosen because of apparently ideal conditions for the establishment of *Metagonistylum*, although the borer (*D. saccharalis*) infestation was normally very low. A total of 222 females was liberated in three separate colonizations at intervals of 3 weeks, during July and August 1951. Establishment was immediate, and by mid-September parasitized borers were common in the fields. On 16/11/51, three months after the last liberation, 7 parasites were recovered in one field from a total of 18 larvae of *D. saccharalis*. As at the Hacienda Tucupido in Aragua, there has not been any setback at La Marroquina—except for the appearance in 1952 of *D. busckella busckella*—and this hacienda has proven a constant source of supply of puparia when replenishment of laboratory stocks became necessary.

The foregoing were the essential results of the campaign in Venezuela during 1951 and 1952, and the negative effects of the introductions in the other colonized areas were definitely disappointing. The writer concluded his Progress Report (7) stating that apart from the Haciendas Tucupido and La Marroquina " it would not be correct to affirm whether positive or negative results have been obtained in other colonized areas, at least until sufficient time has elapsed to enable this to be determined with certainty."

The writer left Venezuela in April 1952, to continue as technical adviser to the Ministry of Agriculture on the campaign of biological control of *Diatraea*, with Señor P. Paredes R. and a trained staff continuing the rearing work at Maracay and following a pre-arranged course of liberations. The whole output of flies since then has been concentrated in reinforcing the three

main sugar-cane areas in Aragua and Lara, and apart from occasional " look-see " examinations, the results of which were becoming more and more frequently " positive ", no systematic survey of the colonized areas was undertaken until the writer's visit of inspection in January-February 1953. The information that follows is extracted from the writer's (unpublished) report on this survey*, submitted to the Director of Agriculture at Caracas on 3/3/53, and the results may best be discussed separately for each of the sugar-cane areas examined.

Aragua : *Upper Rio Tuy and Aragua valleys.*

The situation at the Hacienda Tucupido may be described as a perfect example of the biological control of *Diatraea* on a small scale. The general infestation had become so reduced that it was not possible to obtain a really adequate sample of borers in any one field, so that the samples had to be combined. In two groups of fields (54 acres) of B.37161, plants, $1\frac{1}{2}$-$3\frac{1}{2}$ months old, in which formerly deadhearts would have been abundant at this time of the year, it was possible to collect only 87 ; these produced a total of 40 *Diatraea* stages, with 5/15 (33 per cent.) *saccharalis* and 20/25 (80 per cent.) *rosa* parasitized by *Metagonistylum*, corresponding to an average parasitism of 62 per cent. for both species of borer combined. Three examinations of harvested canes were made, and the average Intensity found to be 9.5 per cent. (formerly 17 per cent.)

Evidence of good establishment in the Upper Rio Tuy valley was obtained at the Hacienda Santa Teresa, and in the Rio Aragua valley at two *haciendas* at La Victoria (El Recreo) and San Mateo (La Quebrada), respectively, in each case *D. rosa* being attacked to at least the same extent as *D. saccharalis*. Conditions at Santa Teresa were especially encouraging, because here the parasite had just become established in a newly planted area of several hundred acres, situated nearly a mile from the nearest point of release. A considerable *Diatraea* population was beginning to build up and deadhearts were frequent to abundant locally ; a sample of 160 deadhearts yielded 101 borers, among which 0/7 (0 per cent.) *saccharalis* and 7/94 (7.5 per cent.) *rosa*, were parasitized. Because of the serious losses sustained by borer damage at this progressive *hacienda* and its subsidiaries in the Aragua valleys, which supply canes for the newly erected " Central Santa Teresa ", the writer recommended to the proprietors that they start immediately an independent campaign, in order to accelerate the otherwise slow natural progress of the introduced parasite. Plans have therefore been made for the production of 1,000 female *Metagonistylum* monthly, for distribution to the contributing *haciendas* during the next two years.

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* The survey covered 72 fields examined on 26 different *haciendas* in Aragua Yaracuy, Lara and Trujillo. A total of 4,053 " deadhearts " and bored stalks yielded 1,982 *Diatraea* stages (including those parasitized). Percentages of parasitism where given are based upon the number of hosts found parasitized at the time of collection plus those from which parasites later developed, expressed as a percentage of the total *Diatraea* stages in the sample ; the hosts were determined to the species except in the case of old residual stages, i.e. " emerged " pupae and puparia. There was never any difficulty in distinguishing larval and pupal *Metagonistylum* from the native dipterous parasites ; see illustrations in Technical Bulletin No. 5 (7).

The general infestation for the 1953 harvest, based on 14 counts at 9 *haciendas*, was 11.0 per cent. Intensity (previous average : 16.0 per cent.)

YARACUY : *Hacienda La Marroquina, San Felipe.*

Because of the recent accidental introduction of *D. busckella busckella* there was a marked increase in the infestation at La Marroquina, in young fields as well as in those approaching maturity. One field being cut for " seed " cane showed an Intensity of 10 per cent. (previous average less than 5 per cent.). Examinations showed that the proportions were approximately 40 per cent. *saccharalis* and 60 per cent. *b. busckella* in young unjointed canes, 75 per cent. and 25 per cent. respectively, in maturing canes.

No flies had been liberated here since March, 1952, but good colonies were found in two fields of advanced plant canes, B.H. 10 (12), 13 months old, showing a moderate borer infestation ; parasitism was 43 per cent. in the population of *saccharalis* (40) and 0 per cent. in *b. busckella* (6).

Since our last visit a new *hacienda* has been established close by, to supply canes for the new " Central San José ", where refined sugar will be produced (La Marroquina producing *papelon*). More than 500 acres have already been planted, and these canefields are among the finest in appearance and potential tonnage that the writer has seen anywhere in his experience. While borer infestation in February was not high, it is imperative to protect this area from any future increase, and therefore a programme of intensive liberations has been planned for the forthcoming season. Although no larvae of *b. busckella* were parasitized among the samples collected at La Marroquina and San José, they were commonly met with later at El Tocuyo, so that there should be no question of ultimate success in this region.

YARACUY AND LARA : *Rio Turbio valley.*

This area comprises some 13,000 acres of cane, distributed among 45 *haciendas*, 3 of which produce refined sugar at their *centrals*, the others producing *papelon*. It extends for about 16 miles from Yaritagua to Barquisimeto, with branches southwards at El Rodeo and Cabudare ; the altitude is from 1,200 ft. to 1,400 ft. It is notorious for its normally heavy borer infestation, and also for annual attacks by froghoppers (*Aeneolamia varia sontica* Fennah). To reduce the damage caused by the latter, large scale drift-dusting with insecticides is in regular operation over a considerable part of the area during the months of June until October. The Amazon Fly campaign was therefore limited to four *haciendas*, later reduced to one (Central Tarabana), where froghopper attacks do not occur and the insecticide hazard is therefore non-existent. Colonizations commenced in May 1951 and have been continued at intervals since then.

The parasite has become firmly established at Central Tarabana over an area of at least 500 acres, including 200 acres of young plants. At the time of our visit of inspection, deadhearts were abundant in these young plant fields, with a borer population (discounting *canella*) of 80 per cent. *saccharalis*

and 20 per cent. *b. busckella* ; 47 per cent. of the *saccharalis* were parasitized by *Metagonistylum*, but none of the *b. busckella*. Other parasitized *saccharalis* were found in neighbouring fields of " high " canes. In one representative sample of 100 deadhearts a total of 22 live parasites were found as puparia or larvae within their hosts, this representing but a fraction of the thousandth part of the total population in this area. This colony will be studied with special attention to the dispersal of the parasites to neighbouring *haciendas*, and the expected transference of parasitism to *b. busckella* as the *saccharalis* population diminishes.

There remains an isolated group of four *haciendas* in the upper part of the valley, near the city of Barquisimeto, where borer infestation is normally very severe, with an average Intensity of 25 per cent. Because of transportation difficulties no flies have yet been released there. To await natural spread from Central Tarabana is no longer justified, and therefore colonizations on a large scale are included in the programme of the campaign for 1953.

Counts made at four *haciendas* showed that there was no material reduction in borer infestation in the area as a whole (actually 16.5 per cent. Intensity, compared with a previous average of 17.5 per cent.), but at Central Tarabana the more advanced fields in which the flies were found established were manifestly far less infested than similar fields in other *haciendas*.

Lara : *El Tocuyo valley.*

This important cane-growing region is centered around the old town of El Tocuyo, now being rebuilt after its almost total destruction by the earthquake of 1950. There are some 8,000 acres actually cultivated, divided among 35 *haciendas*, in one of which—Central Los Palmares—refined sugar is produced, the others producing *papelon* of good quality. In February of the present year, however, the foundations were laid of the new " Central El Tocuyo ", which has been planned to receive and mill canes from the whole area. The promoters of this enterprise are fortunate indeed that a good measure of their future success will be due to the work of the Amazon Fly, because the canefields of El Tocuyo, until now, have suffered more from *Diatraea* than those of anywhere else in Venezuela. Apart from very heavy field losses sustained by the *hacendados*, the quality of the extracted juice is so poor that it is doubtful whether a peak yield of 8.0 per cent. sucrose in cane could have been obtained under past conditions, even with improved extraction, an average of 6.5 per cent. not being considered abnormal.

The writer has thus described the conditions of moth borer attack in the El Tocuyo valley (3) :

> " . . . . there does not exist in any other country a sugar-cane region of such size, which suffers infestations of this magnitude, and never has the writer seen such catastrophic damage to the canes due to *Diatraea**. At El Tocuyo it is a rare thing to find a mature cane

* This was written before the writer was aware of conditions in the State of Sinaloa, Mexico, where the canes suffer damage from *Diatraea considerata* Heinr., in excess even of that observed in the El Tocuyo valley in Venezuela.

that is not perforated . . . the majority having several successive internodes damaged. The worst damage observed was in fields at the Haciendas Goajira Abajo and La Villa Carmen, situated in the valley of the Rio Goajira (a branch of El Tocuyo), at elevation of 2,250–2,500 ft. above sea level . . . The most heavily infested fields had the aspect of having suffered from a severe attack of froghoppers, with 100 per cent. of the canes bored and the majority of them, dead and partially dried up. Counts showed 60 per cent. to be quite unharvestable."

At Central Los Palmares, in the middle part of the valley, joint infestations in excess of 50 per cent., in *P.O.J.*2878 plant cane actually harvested, have been registered on more than one occasion. The total loss from *Diatraea* damage at El Tocuyo has been conservatively estimated at not less than 33 per cent. of the potential production.

The general surroundings are of an induced xerophytic type, resulting from the destruction of the original forest vegetation by indiscriminate cutting, forest fires and the depredations of innumerable goats, over a period of more than three centuries. At the present time many of the surrounding hills and mountain-sides are bare of vegetation, and in the valley itself the un-irrigated parts support no more than a growth of Cactaceae and various spiny leguminous shrubs and small trees growing among boulders and stones. The average annual rainfall is less than 20 inches. The *haciendas* depend entirely on irrigation water carried by the El Tocuyo and its tributaries, the sources of which have a doubtful future because of the constant burning of the forested watersheds. Nevertheless, the arable soils are good, and the general standard of cane cultivation is high. The main limiting factor has been the constant heavy moth borer infestation, due to three species, *D. saccharalis*, *D. busckella busckella* and *D. impersonatella*, which attack canes of all ages, and *D. canella*, which is primarily a pest in young ratoons. Often the four species could be found in one and the same field, and some fields have been seen in which more than half of the growing canes were killed from the multiple attack.

Parasitism of *Diatraea* by the native tachinids normally is rare at El Tocuyo, and only twice has *Paratheresia* been found there, in each case reared from larvae of *D. b. busckella*. The discovery in February 1953 of good colonies of *Paratheresia* at two *haciendas*, attacking *D. saccharalis* as well as *D. b. busckella*, is considered to be the result of the liberation of *PT* and *PV* x *T* in 1951 and 1952.

The first liberations of *Metagonistylum* were made in May 1951, when 103 females were distributed to three haciendas, followed by 3,260 puparia in June. Further lots, totalling 602 females, were released in these same *haciendas*, plus one other, during November and December, and in 1952 the area received strong reinforcements at all the earlier points of release.

A preliminary examination of some of the colonized areas was made in March 1952, and included samples of bored canes taken from the fields where flies had earlier been liberated. The results were in every case negative, and it was thought that the high altitude and arid conditions of the habitat might prove to be insuperable adverse factors. Notwithstanding, the campaign continued, and when the survey of February 1953 was made the situation had completely altered, and was beyond our best expectations. The following is extracted from the writer's report :

> "We found the parasite established in three well-separated *haciendas* representative of the (upper) western part of the valley, viz. El Molino, Buena Vista and Goajira Abajo, and without doubt it would have been possible to find the parasite in any other *haciendas* here, had they been visited. The parasite is attacking the borers in canefields of all ages including even the youngest, in which the first generations of borers are being eradicated. Based on samples taken from nine typical fields in this part of the region, it may be stated that approximately 20 per cent. of the total *Diatraea* population is succumbing to the attacks of the fly, over an extension of not less than 3,600 acres. The rate of parasitism varies from field to field, the highest encountered being in a young ratoon of *B.H.* 10 (12), 1½-2 months old, in the Hacienda Goajira Abajo ; this sample gave the following figures of mortality among borers in a total of 50 deadhearts · *D. saccharalis* 50 per cent., *D. b. busckella* 25 per cent., *D. impersonatella* 9 per cent. (It will be remembered that at San Felipe and at Central Tarabana no larvae of *D. b. busckella* were found parasitized by *Metagonistylum*). From the quantity of residual puparia found in bored canes, it was judged that the parasite's attack was by no means new, and consequently there was a perceptible reduction in the infestation in this zone. In truth, for the first time we have seen fields at El Tocuyo almost free from borer, in some of which it was difficult to secure a sufficient sample of damaged canes.
>
> Even better was the situation at the Hacienda El Molino. The whole area that had been colonized with *Metagonistylum* and *Paratheresia* in 1951–52 has been harvested, ploughed, and re-planted ; over some 340 acres there were now only young plants less than 3 months old. Throughout this block of fields deadhearts were extremely scarce, and working for an hour all of us could collect only 112, which yielded 37 *Diatraea* stages : *saccharalis* 16, *b. busckella* 15, *impersonatella* 4, *canella* 2 ; with 3 (19 per cent.) of the *saccharalis* parasitized by *Metagonistylum* and 3 others (19 per cent.) parasitized by *Paratheresia* ; one larva of *b. busckella* (6 per cent.) was parasitized by *Metagonistylum*".

The fact that the introduced parasites were working where there was a minimum of potential hosts available in the fields, as well as where they were abundant, is considered as indicating their adaptation to the habitat, and we

feel that the future control of the borer in this area is now assured. " The excellent condition of the new canes in comparison with those now being harvested is sufficient proof of the effects of the introduction of *Metagonistylum*, and we have every confidence that the present will be the last harvest at El Tocuyo with infestations classifiable as ' very severe ' and ' catastrophic ', which until now have been the normal in this part of the country."

The campaign in Venezuela henceforth will be concentrated in those areas which have not yet shown definite results and those which have not yet been colonized. We are satisfied that the Amazon Fly is adaptable to a very wide range of " general ecological conditions ", varying from the comparatively low-lying tropical jungle area in the Yaracuy valley to the extremely arid mountainous region of El Tocuyo. The parasite attacks *D. rosa* equally as well as *D. saccharalis*, and is developing the ability to attack *D. busckella busckella* and also *D. impersonatella*, under field conditions.

But perhaps the most valuable lessons learned from this campaign are the proven fallibility of the still popular " hit or miss " method of Biological Control, and that success may be achieved by perseverance even when the early indications may be far from encouraging. Too many of the so called failures in similar ventures are due, in the writer's considered opinion, to their having been abandoned at their most critical yet most promising stage.

Acknowledgements

The writer desires to place on record his appreciation of the constant and unfailing support that he has received from the Directors of Agriculture who were in office in the Ministry during the period of his engagement, as well as the co-operation of many *hacendados* in Venezuela. He would state furthermore that the successful issue of this campaign would not have been possible without the assistance and goodwill of his staff, especially Señor P. Paredes R., Señor P. Guagliumi and Señor F. Mejias. To all of the above the writer would express his feelings of gratitude and sincere thanks.

Note on *Metagonistylum minense* Tns. in the Delta Amacuro Territory, Venezuela

A discovery of very great interest has been made and communicated by Dr. Francisco Fernández Yépez, present Head of the Division of Entomology, National Institute of Agriculture, Maracay. In December, 1952, he took part in the " La Salle Expedition " to carry out entomological studies in the Orinoco Delta region, Delta Amacuro Territory. Examining natives' small plots of sugar-canes in the vicinity of Curiapo, he found a slight infestation of the borer, *Diatraea saccharalis* (F). Among the larvae that he collected was one obviously attacked by a dipterous parasite ; this yielded a puparium from which an adult of the Amazon Fly later emerged at the Maracay laboratory, where it was seen and determined by the writer. *M. minense* is not native to this region and the only possible explanation of its presence there is that it has spread from British Guiana, where it was introduced by the late

Dr. J. G. Myers in 1933, the example found by Dr. Fernández Yépez being the progeny of Mr. L. D. Cleare's colonizations of the sugar plantations on the River Demerara in 1934. The parasite has evidently found conditions congenial for its multiplication and spread in water-grasses (inhabited by *D. saccharalis*) along the rivers in this area, for it has now been found at a distance of 190 miles (in a straight line) from the nearest point of release eighteen years ago.

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YIELD DISTRIBUTION OF ESTATE COCONUTS

BY

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In the course of recording coconuts yields of manurial trials (Murray & Lucie Smith, 1953), the distributions of the first year's yields on two estates have been examined. Since a coconut takes approximately one year from pollination to maturity the manures applied may be assumed to have had no effect on the numbers of nuts harvested. Nuts harvested in the first year would have set prior to the manurial applications.

The numbers of trees giving yields in classes of 10 for the two estates are given in Table I.

TABLE I.—*Frequency Distribution of Yields*

No. of Nuts	Number of Trees	
	Estate A	Estate B
Blanks	61	32
1– 10	8	8
11– 20	13	16
21– 30	13	25
31– 40	15	26
41– 50	24	37
51– 60	41	40
61– 70	40	29
71– 80	52	25
81– 90	30	16
91–100	50	12
101–110	42	11
111–120	49	8
121–130	44	6
131–140	20	2
141–150	16	4
151–160	15	2
161–170	11	1
171–180	12	
181–190	3	
191–200	4	
201–210	2	
211–220	2	
221–230	1	
231–240	—	
241–250	1	
...	—	
291–300	1	
Total trees	572	300
Total nuts	45,549	16,264
Average per tree ...	83	54

The point of interest lies in an examination of the proportion of the total yield contributed by the best yielding trees.

For Estate A, there are 52 trees giving yields of over 150 nuts per annum. These trees constituting 9 per cent. of the total gave 21 per cent. of the total crop. Lowering the standard to trees giving more than 130 nuts per annum, 15 per cent. of the total number of trees have given 30 per cent. of the crop.

Similarly, for Estate B, 15 trees gave more than 120 nuts per annum i.e. 5 per cent. of the trees gave 13 per cent. of the crop. At the lower standard of more than 100 nuts per tree, 11 per cent. of the trees gave 25 per cent. of the crop.

There is clearly considerable scope for selection among this material. The coconut is a crop which may occupy the land for 70-80 years and it is of importance to plant selected material with high yield potentiality. The coconut being normally cross pollinated, selection of high yielding mother trees will not be sufficient to provide good seed nuts, for the male parent will be unknown.

A selection programme has therefore been started in which nuts from high yielding estate trees have been planted in isolation from other coconuts at the Central Research Station. The selection standard adopted has been the estimated production of 50 lbs. dry copra per tree per annum. When these trees come into bearing poor yielders will be cut out and the block will therefore contain only high yielding trees. This block will serve for the production of high yielding seed nuts for estate planting.

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OBSERVATIONS ON THE ROOT SYSTEM OF GUATEMALA GRASS ON AN UPLAND TEA SOIL IN CEYLON

BY

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Introduction

A large part of the total of 600,000 acres of tea grown in Ceylon is situated in the central hills (elevation 2,500 to 6,000 feet) where an annual rainfall of from 100″-200″ is experienced.

The parent rocks of this area are chiefly schists, gneisses and granites of the charnockite series (1) and give rise on weathering, under the humid conditions prevailing, to highly acid red humic latosolic soils, black humic latasols and, at elevations of 6,000 feet or more, humic podsolic soils. It is on these soils that the bulk of Ceylon's tea is grown. The industry has been established in this area for about eighty years and much of the tea is now approaching the age when uprooting and replanting will have to be considered. In addition the success of vegetatively propagated clones (2), which combine high yielding capacity with resistance to blister blight leaf disease (caused by the fungus *Exobasidium vexans*), has brought the question of replanting into the foreground.

The tea crop having occupied the ground for a very long period of years, it has been suggested that between the uprooting of the old tea and the replanting of the new, the soil should be rested under some other crop. Although this rotation of crops is a well established practice in temperate agriculture, it is as yet little used in tropical areas and may indeed be inapplicable to areas such as typical Ceylon tea soils which are highly acid and on which very few crops, especially short-lived perennials, will grow. There are possible reasons for a break under another crop from the plant pathological point of view, but these need not be discussed here. On experimental areas Guatemala grass (*Tripsacum laxum*) is being grown as an intermediate crop during the resting period, and it is the purpose of this communication to indicate what effect this grass has on the organic matter status and structure of a typical upland tea soil.

The use of a grass as a fallow crop in tropical areas is not new, since elephant grass has been used in this way in Uganda for many years (3) and a variety of grasses have been used in Trinidad, British West Indies.

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Guatemala grass has been chosen for trial on Ceylon tea soils for several reasons. It is rather a coarse grass and, although it is used as a fodder in some countries (4), it is not favoured by cattle keepers in Ceylon and is therefore unlikely to be stolen ; it grows well under a variety of soil and climatic conditions and is drought resistant. Under normal conditions of cultivation in Ceylon it is lopped at between 12″–18″ from the ground, but when it is desired to remove the grass a single cutting down to ground level in wet weather has been found to kill out more than 90 per cent. of the grass stools. This means that it can be removed from a given area without any disturbance of the soil, a fact of importance since most of the upland tea is grown on slopes with gradients of more than 1 in 6 and much of it on gradients of 1 in 3.

Experimental

A description of a typical profile of the soil on which these experiments were carried out is given in Table I. The chief features of this soil type are

Table I *Profile description. Site of main excavations*

Depth	
0″–12″	Uniform dark brown to black highly humic (10% O.M.) top soil of excellent structure.
12″–24″	Transition zone through yellow brown slightly bleached clay, with coarse gravel layers about 1″ thick irregularly placed to yellowish red clay.
24″–30″	Final transition to deep red clay.
30″–10′	Uniform concolorous red clay of good prismatic structure. Abundant micaceous fragments in evidence. Freely drained.

the high organic status (10 per cent.) of the surface soil and the extreme water stability of the soil as a whole. The high organic matter status is associated with high acidity (pH 4.4 to 5.2. Soil : water as 1 : 2.5) and a low base exchange capacity of the order of 15 mg. eq. per 100 gms. of soil. Eden (5) has already drawn attention to the excellent physical condition of these soils and it was, therefore, to be expected that Guatemala grass would have relatively little effect on the structure of such soils.

Aggregate Analysis

Twelve soil cores 6″ diameter x 6″ deep were taken at random points in each of three areas of a uniform field. The area carried tea about thirty years old (A), Guatemala grass two years and three months old (B), and newly planted tea (C) respectively. The newly planted area had been kept under Guatemala grass for a two-year period, after which the grass had been killed. When the soil samples were taken some 9 months had elapsed from the time of this cutting operation.

The soil samples were brought to the laboratory, carefully crushed into clods and subjected to aggregate analysis by the Yoder method (6). The samples were not allowed to dry before analysis since trials had shown that the moisture contents of the samples were sensibly uniform.

The results of this analysis are shown in Table II.

TABLE II. *Percentages (on oven dry basis 95°C) of various sized water stable aggregates in soil from :*

A. field under tea for 30 years.
B. same field after 2 years under Guatemala grass.
C. same field 9 months after removal of the Guatemala grass.

Aggregate size mms.	A	B	C	t for specified pairs of means
5.0	26.4	28.4	24.8	
6^2 (n = 12)	56.659	43.129	18.505	
2.0–5.0	5.03	6.97	6.19	t (B-A) = 5.03***
6^2 (n = 12)	0.769	1.023	1.746	t (C-A) = 2.53*
1.0–2.0	14.2	20.8	18.3	t (B-A) = 5.49***
6^2 (n = 12)	10.247	7.425	3.841	t (C-A) = 3.85***
				t (B-C) = 2.57*
0.2–1.0	17.7	21.0	17.9	
6^2 (n = 12)	25.252	18.985	4.324	t (B-C) = 2.27*
Total > 0.2	63.5	77.2	67.3	t (B-A) = 4.63***
6^2 (n = 12)	41.801	63.352	32.504	t (B-C) = 3.56**
Values of t (n = 22)	5% = 2.074			
	1% = 2.819			
	1% = 3.792			

The soil from the area under grass showed a significantly higher total amount of aggregates greater than 0.2 mms. than the soils from the area under old tea and from the newly planted area. It would appear, therefore, that although there is a definite improvement of structure consequent on the growth of the grass the improvement is lost within nine months of the grass being killed out. Further examination of Table II shows that the increase is of aggregates within the range 1.0–5.0 mms, the percentage of the higher sized aggregates > 5.0 mm. being unaffected.

EXAMINATION OF THE ROOT SYSTEM OF GUATEMALA GRASS

Although the contribution made by the roots of crop plants to the organic matter status of the soil is known to some extent for temperate crops (7) there is very little quantitative information with regard to tropical crops. The root system of sugar-cane has been exhaustively investigated by Evans (8) but not primarily from the point of view of the contribution made by the roots to the organic matter status of the soil. Hardy (9) and Lee *et al* (10) have shown that the total root weight of sugar-cane is relatively small. Little work has been done on other tropical grasses.

On a part of the grass area (B) referred to previously, 4 pits were dug each 10 feet deep. Successive 6″ layers of soil were removed, by means of a 9″ square sampling box, from a representative face of each pit.

The equivalent samples from the four pits were bulked and the roots recovered by flotation in water. The roots were carefully washed, dried and weighed. On ashing, a total ash content of between 9-11 per cent. was found on various samples, and it was therefore concluded that there was little soil remaining on the roots as weighed. The distribution of the roots with depth is shown in Table III.

TABLE III. *Distribution of roots of Guatemala grass (Tripsacum laxum)*

Depth	0″–6″	6″–12″	12″–18″	18″–24″	24″–30″	30″–36″	3′–10′	Total
Dry roots tons per acre ...	5.8	5.3	3.1	1.8	1.4	0.8	1.0	19.2

The most remarkable finding was the considerable weight of roots per acre developed by this grass. The figure of some 19.2 tons per acre is more than four times the figure given by Weaver *et al* (11) for established prairie areas in Canada.

The deep distribution of the roots, though not unusual for grasses (12 and 13) is interesting since on the same soil the main root system of the tea bush does not penetrate more than about 18″ (14). Penetration of the grass roots below the 3 feet level was chiefly down natural fissure planes between the prismatic type structural units of the soil.

In view of the exceedingly high weight of roots per acre found from the foregoing experiment, core samples 6″ diameter by 6″ deep were taken from areas of other grasses growing on another area of similar soil on St. Coombs Estate. Twenty-four samples were taken from each area and the roots were extracted by flotation in water as before.

The results of the experiment are given in Table IV.

TABLE IV. *Weight of roots in top 6″ layer of soil under different grasses*

Grass	Age (months)	Site	Wt. dry roots tons per acre
Tripsacum laxum	27	Patna	5.8
Pennisetum purpureum	15	Garden	4.0
do. do.	48	do. (gravelly)	2.0
Paspalum urvillei	36	Garden	5.3
Patna grassland (*Andropogon nardus* Assn.)	—	Irregularly burnt patna area	5.3
Axonopus compressus	15	Garden	3.0

N.B. Stools and/or rhizomes are not included in these figures.

No deeper excavations were carried out in this case, but the amount of roots found in the top 6″ of soil confirm the magnitude of the root weight per acre found in the previous experiment.

Discussion

The increase in the total amount of water-stable aggregates brought about by a two year period under Guatemala grass, although statistically significant, is probably not of major agricultural importance on this particular soil type for the structure is in any case very good. Such improvement of structure as is obtained is very quickly lost when the grass is removed. This result accords well with observations made in Trinidad by Hardy (15) and by workers in Uganda.

However, the production of some 19 tons of roots per acre may be of considerable value. The aerial parts of the grass during the same period produce about 120 tons of fresh grass or about 20 tons of dry matter per acre. It will be seen, therefore, that the production of organic matter in the form of roots is about the same as the production of organic matter above the ground. The organic matter in the roots has the additional advantage of being intimately distributed throughout the soil mass in a way which it is quite impossible to achieve by mechanical incorporation.

The total organic matter contribution of some 40 tons per acre in a two year period is in itself high, but since the soil in the experimental areas already contained some 200 tons per acre of soil organic matter, the value of the addition of this further quantity might be questioned.

However the added organic matter is rapidly broken down at the fairly high soil temperatures prevailing and, although the organic matter status of the soil may not necessarily be increased by the addition of such a large amount of easily decomposable organic residues (16), it can be expected to provide a supply of readily available nutrients for the succeeding crop. (20 tons Guatemala grass roots contain approximately 224 lbs. nitrogen, 75 lbs. of phosphorus and 600 lbs. of potassium). If leguminous cover crops are planted immediately after the grass is cut down a temporary phosphate deficiency has been encountered (17), but this deficiency is shortlived.

Since the soil itself is relatively poor in nutrients readily available to the tea bush, the provision of a considerable supply of readily available nutrients by the decomposing grass residues may well be of more importance than the other functions of the grass, namely, improvement of the soil structure and the provision of a large amount of organic residues.

Summary

1. The effect of a crop of Guatemala grass on the state of the aggregation of a typical upland tea soil in Ceylon has been examined.

2. A statistically significant increase in the total amount of aggregates > 0.2 mm. has been found.

3. This improved structure is lost within nine months of the removal of the grass.

4. The root system of Guatemala grass has been examined and the total weight of the roots per acre has been estimated.

5. It is concluded that the most important function of the added organic matter on the particular soil type in question may well be the provision of a supply of readily available nutrients for the succeeding tea crop.

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INSECT PESTS OF SUGAR-CANE IN THE FRENCH ANTILLES

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THERE are very few records from the French Antilles of insects attacking sugar-cane, and in a recent publication Box (1953 a) specifically draws attention to the fact that from Martinique "practically no records of sugar-cane insects seem ever to have been published." On a recent visit to Guadeloupe and Martinique several insects were observed attacking sugar-cane, and in addition information was obtained on the present status of the main cane pest, *Diatraea saccharalis* F., and its parasites. The following is an account of the insects noted, and of the possibilities for further biological control of *Diatraea*.

Species observed

(+ indicates present, — definitely absent, ? not observed)

		Guadeloupe	Martinique
Lepidoptera			
Pyralidae			
	Diatraea saccharalis F.	+	+
	Parasites : *Trichogramma minutum* Riley	+	+
	Prophanurus alecto Crawf. ...	+	+
	Agathis stigmatera Cress. ...	+	+
	Metagonistylum minense Tns.	+	+
	Lixophaga diatraeae Tns. ...	+	—
	D. canella Hmps.	—	+
Agrotidae			
	Laphygma frugiperda S. & A.	+	+
Coleoptera			
Curculionidae			
	Metamasius hemipterus (L.)	+	+
Hemiptera			
Delphacidae			
	Saccharosydne saccharivora West.	+	+
Lygaeidae			
	Blissus leucopterus insularis Barber	?	+
Aphididae			
	Sipha flava Forbes ...	+	+

Species observed	Guadeloupe	Martinique
Coccidae		
Saccharicoccus (*Trionymus*) *sacchari* Ckll.	+	+
Orthoptera		
Acridiidae		
Schistocerca pallens Thunb. ...	+	+

In addition larvae of *Diaprepes* sp. and of a Phyllophagan were found in small numbers at Marquisat in Guadeloupe attacking cane roots. Also in Guadeloupe several unidentified Hesperid larvae were observed, one of which was parasitized by *Euplectrus* sp. Termites were also seen attacking dry cane in both islands.

Diatraea saccharalis was abundant everywhere and is certainly the major pest of sugar-cane in the islands. *D. canella*, found only in Martinique, was uncommon, and of some 300–400 *Diatraea* larvae examined in Martinique only five were *D. canella*. Larvae of this species were also found in razor grass, *Paspalum virgatum*. It is possible that the status of *D. canelia* may change with some future change in the cane varieties grown or variation in other factors. Such an alteration in the proportions of the three *Diatraea* species attacking cane has been noticed in Trinidad during the past twenty years (*see* Simmonds 1948). One curious fact was noticed. The variation of the markings of *D. saccharalis* larvae in both Guadeloupe and Martinique is far greater than has been observed elsewhere. Some appear to be indistinguishable from those of *D. impersonatella* Walk. in Trinidad. Others, Mr. Box considers very similar to larvae of *D. rosa* Heinr. However, reared through to adults these all proved to be *D. saccharalis*.

The introduced Tachinid larval parasites *Lixophaga diatraeae* and *Metagonistylum minense* are widespread in Guadeloupe but only the latter species occurs in Martinique where it, too, is common. The egg parasites *Prophanurus* and *Trichogramma* were found in both islands, and a single example in each of the larval parasite *Agathis stigmatera*. In spite of these parasites *D. saccharalis* is abundant and causes very serious damage.

Laphygma frugiperda is said to cause localised damage periodically in the islands by defoliating young cane.

In 1952 the weevil *Metamasius* caused heavy losses in Martinique when a very rapid build up of its population occurred after a hurricane had damaged a large amount of mature cane. However, this is a secondary pest, only attacking cane already damaged by *Diatraea*, rats, wind, &c., though females may oviposit in the splits normally occurring in certain varieties of cane (e.g., B.34104). Increased losses may occur in "standover" cane where other forms of damage are more common.

In both islands in localized areas the leaf hopper, *Saccharosydne saccharivora*, was common. Egg masses, nymphs and adults were plentiful on cane leaves and damage from feeding punctures in the leaves was quite apparent. *Blissus* was found commonly on sugar-cane in some areas in Martinique, and the aphid, *Sipha flava*, was found in both islands to be causing damage in some fields of young cane. An unidentified Jassid was also common on cane leaves in Martinique.

The mealybug, *Saccharicoccus* (*Trionymus*) *sacchari* was abundant on cane in both Martinique and Guadeloupe, and was seen also in the Iles des Saints. The predacious Coccinellid, *Hyperaspis trilineata* Muls., was not present.

The status of *Diatraea saccharalis* is interesting since Guadeloupe is the only area where the two Tachinid parasites *Lixophaga* and *Metagonistylum* exist together. In Martinique only *Metagonistylum* has been established, and as far as can be ascertained this occurred in 1934 when material was brought over from St. Lucia and released. This species is now widespread in Martinique. Thence it was introduced into Guadeloupe in 1938 where it also became quickly established. In 1947–48 *Lixophaga* was introduced into Guadeloupe and also became well established. There is unfortunately, no definite record of the exact dates of these introductions and the above is open to correction.

There are, moreover, no figures indicating what effect these introductions had on the incidence of borer, but generalised statements by planters indicate that prior to the introduction of *Metagonistylum* borer infestation was very severe, and was considerably reduced when this parasite became established. Before World War II, when older varieties, including a considerable proportion of B.H. 10/12, were grown, *Diatraea* damage was not considered severe (although there are no definite figures of joint infestation). After the war, due to changed economic conditions, it was impossible to grow B.H. 10/12 on a large scale owing to the need for considerable manual cultivation with this variety. Naturally use was made of the newer high yielding varieties, including B.34104, B.37161, B.3337, B.4098, and, more recently B.41227 and B.4362. It was soon found, however, that borer infestation rose rapidly, and at present the joint infestation of mature cane must in both islands average, at a very conservative estimate, about 10%, being much higher in plant canes, lower in general in ratoons. This entails a reduction of at least 5% in yield of sugar which represents an enormous annual financial loss. Apart from this reduction there is a serious loss in fields of young cane, where a considerable proportion of shoots and young canes may be killed when they are 2–4 months old. In a number of such fields examined it was obvious that, owing to heavy *Diatraea* attack, the majority of the young canes then standing would be killed, and that it would be only from subsequent shoots that millable cane would be produced. Thus a field cropped 18 months after planting would, in fact, consist of 14 months old cane, with an obvious loss of growing time, tonnage of cane per acre, and a proportion of any fertiliser applied in the early stages.

This startling increase in *Diatraea* infestation following the widespread planting of some of the newer cane varieties has also occurred elsewhere (e.g., Trinidad, St. Kitts) and the exact reason for this should be investigated. It seems possible that, apart from any preference by ovipositing female moths for any individual varieties, two other factors may operate to produce this increase in attack. Differences in the degree to which trash clings to the cane, and in the hardness of the rind, may produce a different mortality of young larvae between the time of eclosion and the actual beginning of their burrowing into the cane. Some of the newer varieties may be more nutritious for the developing larvae, which may then grow larger than on the older canes and give rise to females capable of laying a greater number of eggs. Both of these factors would produce, with extensive planting of favourable varieties, an overall increase in *Diatraea* population.

In the French Antilles this increase has taken place in spite of the presence of the introduced larval parasites, and it may be assumed that, without these parasites the borer situation would be considerably worse.

Metagonistylum (the Amazon strain) has always been considered to be a species adapted to areas of high rainfall, *Lixophaga* to much drier conditions. The distribution of the two species in Guadeloupe bears this out to a certain extent. As judged from the few small samples it was possible to take during the time available, the relative abundance of the two species in Guadeloupe differed in different areas. In Guadeloupe proper, with its higher rainfall, *Metagonistylum* was more common, whereas at the extreme eastern part of Grande Terre, which is very dry, nearly all the parasites found were *Lixophaga*. Between these extremes both species occur in varying proportions. The main point of interest in this regard is that even in the dry areas *Metagonistylum* is able to maintain itself, as does *Lixophaga* in comparatively wet areas. Each species seems to be more adaptable than has hitherto been supposed. It is interesting to note that at this same time Box (1953 *b*) was in Venezuela and found that after earlier introduction by him *Metagonistylum* had become well established in an extremely dry area near El Tocuyo.

In Martinique *Metagonistylum* was found in every area visited, but these did not include the drier section around Le Marin. It was not found in the drier lower cane fields near Carbet but occurred higher up in the same area where rainfall was greater, and here, too, was found to have parasitized *D. saccharalis* to a high degree in maize stalks.

Unfortunately, no samples of *Diatraea* larvae from cane of different ages have been made to determine the course of changes, if any, in the degree of parasitism of borer larvae, and incidence of borers at various stages in the developing cane. It is obvious, however, that the borer population in young cane is enormous ; and it is probable that through the action of parasites there is considerable reduction in the number of adults present at the later stages of growth of the cane. Consequently, borer damage in older cane is thus reduced. However, it is also obvious that at present, parasitic action is insufficient to prevent considerable losses due to *Diatraea*.

There are no known cultural methods of definite value in reducing borer damage in the tropics, also, owing to the fact that oviposition by *Diatraea* occurs the year round and that rain often falls in very heavy showers the use of present known insecticides against *Diatraea* has been ineffective The rate of growth of the cane also contributes to this. To give adequate coverage of cane leaves insecticides would have to be applied at far too frequent intervals to be economically possible. There remain two methods of control—the breeding of cane varieties resistant to *Diatraea* attack, and an increase in the effectiveness of biological control. Unfortunately, the qualities of a cane desirable from a planter's and a factory's point of view seem in general to be those favouring a heavy *Diatraea* attack, and to date, in the tropics, little attention has been paid to this aspect of cane-breeding.

With regard to obtaining more effective biological control in the French Antilles, the introduction of another Tachinid parasite of the larvae, *Paratheresia claripalpis* Wulp., should be tried. This species occurs in Trinidad and on the mainland of South and Central America, there being apparently several geographical races differing in their exact host preferences and biological characteristics. In Trinidad *Paratheresia* is chiefly a parasite of *D. saccharalis*, both in cane and corn, and at certain times of the year (particularly April–May) it attains a parasitism of 40–50% in some areas. It is also reared, but less commonly, from *D. impersonatella* Walk., and very rarely from *D. canella* Hmps., both occurring in cane, and very rarely from *D. lineolata* in corn. Puparia of *Paratheresia* are attacked in Trinidad by secondary hymenopterous parasites (e.g., *Trichopria* sp.) which may reduce its efficiency in controlling *Diatraea* later in the season. Examination of a number of puparia of *Metagonistylum* and *Lixophaga* in the French Antilles gave no indication that similar secondary parasites occur there. Hence if *Paratheresia* is established it may be more successful than in Trinidad. This species occurs in all the sugar growing areas in Trinidad and it would therefore appear suited to the climate of both Martinique and Guadeloupe excepting possibly the very driest areas.

Since there are already two common larval parasites in Guadeloupe and one in Martinique *Paratheresia*, if established, would be in competition for hosts with these other species as their life cycles are all very similar. It is often seen in the field that a large *D. saccharalis* larva may produce not one but several parasite puparia, and *Metagonistylum* and *Lixophaga* puparia are sometimes produced from the same host. In the laboratory experiments have been carried out using smaller *D. saccharalis* larvae capable of supporting to maturity only a single Tachinid parasite, and inoculating these hosts with *Metagonistylum*, *Lixophaga* and *Paratheresia* grubs, one of each of two species at one time or with a three day interval between inoculations. Details of these experiments will be given elsewhere, but in general it is found that *Lixophaga* and *Paratheresia* are intrinsically superior to *Metagonistylum*, which with its higher fecundity is extrinsically superior to either; neither *Paratheresia* nor *Lixophaga* shows marked intrinsic superiority over the other when in competition in the same host. Such interaction of parasites in the same host only plays an important part in affecting populations of

parasites when parasitism is high, and in this instance there is no reason for rejecting the introduction of *Paratheresia* on the assumption that it will affect adversely the parasitism produced by the other larval parasites. It is likely that slight local variation in climatic conditions would favour one or other of the parasite species at different times and that, in general, the addition of *Paratheresia* to the parasite complex would result in an overall increase in the general level of parasitism. Even if this were not very great it might be sufficient, in conjunction with other factors causing mortality of *Diatraea*, to check the increase in *Diatraea* population early in the season, and to produce appreciable economic benefit.

It is obvious in both islands that at present parasite activity is insufficient to prevent fields of young cane from becoming heavily attacked by borer, and it may be that parasites enter these young fields too late or in insufficient numbers to prevent a very rapid build up of the *Diatraea* population, which is then only brought under control by parasites comparatively slowly. In view of the enormous losses sustained by the industry it is worth while attempting any method which might prevent this early increase in borer population. It is possible that, by increasing artificially the population of adult parasites at a critical time in the young cane fields when borer larvae are plentiful but parasitism is comparatively low it might be possible to augment parasitism to an extent such that a subsequent increase in *Diatraea* infestation was prevented. Such a procedure is claimed to be effective, under somewhat different circumstances, in Cuba and Florida. Any trial of it, however, must be regarded as entirely experimental, and careful data on parasitism obtained, by means of field samples of larvae, before and after any releases that are made. These releases should be on a sufficiently large scale to ensure that there is an adequate increase in the numbers of parasites present in the area. Comparison of the degree of parasitism before and following releases, together with a check on the subsequent course of *Diatraea* populations in both "release" areas and control areas where no releases have occurred, should give indications as to whether this method is of practical value. Without careful study of conditions no information as to the value of this method can be obtained. It cannot be stressed too much that the present losses in both Guadeloupe and Martinique due to *Diatraea* are so great that careful investigations by means of adequate extensive sampling should be carried out and any promising method of control should be given an extended but carefully checked trial on an adequate scale.

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